SEPTEMBER 1961

VOL. 53 • NO. 9

Journal

AMERICAN WATER WORKS ASSOCIATION

High service area—the customers may bring their own supply

In this issue:

NATIONAL WATER NEEDS
Kerr

SALINE-WATER CONVERSION
Task Group Report, Leitner

WATER SUPPLY ON THE MOON
Lowe

WATER CONSUMPTION BY INSTITUTIONS
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TELEMETERING
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RUPTURE CONTROL IN GAS PIPELINES
Stannard

LIME SLUDGE DISPOSAL
Howson

DISTRIBUTION MANUAL
AWWA M8

STEEL PIPE DESIGN AND INSTALLATION
Committee Report

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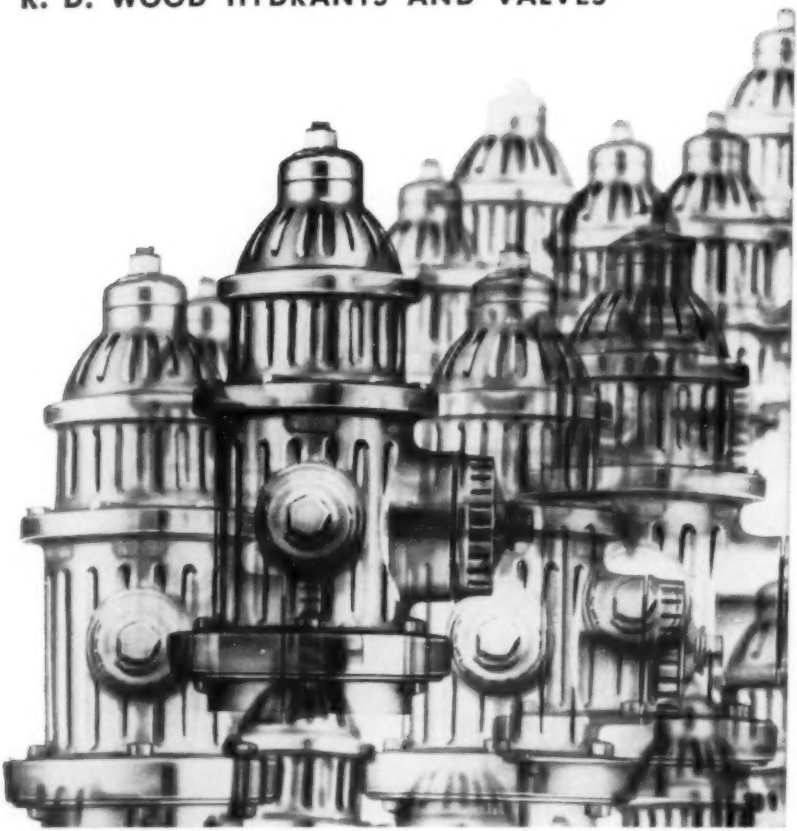

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Journal

AMERICAN WATER WORKS ASSOCIATION

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September 1961
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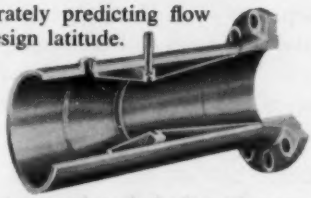

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Coming Meetings

AWWA SECTIONS

Fall 1961

Sep. 20–22—South Dakota Section, at Sheraton-Johnson Hotel, Rapid City. Secretary, J. Darrel Bakken, Div. of San. Eng., State Dept. of Health, Pierre.

Sep. 27–29—Wisconsin Section, at Hotel Schroeder, Milwaukee. Secretary, Harry Breimeister, Bureau of Engineers, Room 607 Municipal Bldg., 841 N. Broadway, Milwaukee.

Sep. 28—Connecticut Section, at Maisel's Grantmoor Restaurant, Newington. Secretary, D. W. Loiselle, Supt. of Supply, Bridgeport Hydraulic Co., 835 Main St., Bridgeport.

Oct. 1–3—Missouri Section, at Kentwood Arms Hotel, Springfield. Secretary, Warren A. Kramer, Chief, Water Supply, Div. of Health, State Office Bldg., Jefferson City.

Oct. 2–3—Martime Branch, Canadian Section, at Brunswick Hotel, Moncton, N.M. Secretary, J. D. Kline, Gen. Mgr., Public Service Com., 162 Lady Hammond Rd., Halifax, N.S.

Oct. 2–4—Rocky Mountain Section, at La Katchina Hotel, Taos, N.M. Secretary, H. F. Kepner, Vice-Pres., Dana Kepner Co., 550 Alcott, Denver, Colo.

Oct. 4–6—Virginia Section, at Hotel Roanoke, Roanoke. Secretary, Edward H. Ruehl, R. Stuart Royer & Assocs., 15 W. Cary St., Richmond 20.

Oct. 5–6—Intermountain Section, at Twin Falls, Idaho. Secretary, M. W. Snell, Supt., Power & Water, Soda Springs, Idaho.

Oct. 8–11—Alabama-Mississippi Section, at Buena Vista Hotel, Biloxi, Miss. Secretary, Ernest Bryan, Southern Sales Mgr., McWane Cast Iron Pipe Co., Box 2601, Birmingham, Ala.

Oct. 15–18—Southwest Section, at Granada Hotel, San Antonio, Tex. Secretary, L. A. Jackson, Mgr.-Engr., Municipal Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 18–20—Iowa Section, at Roosevelt Hotel, Cedar Rapids. Secretary, Wilbur E. Bjork, Service Supt., Des Moines Water Works, 1003 Locust St., Des Moines.

Oct. 25–27—California Section, at Hotel Senator, Sacramento. Secretary, Frank F. Watters, Hydr. Engr., State Public Utilities Com., State Bldg., Civic Center, San Francisco.

Oct. 25–27—Ohio Section, at Commodore Perry Hotel, Toledo. Secretary, J. H. Bass, Henry P. Thompson Co., 4866 Cooper Rd., Cincinnati.

(Continued on page 8)

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by the carload to meet San Jose Water Works' growing requirements

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Coming Meetings

(Continued from page 6)

Oct. 25–28—New Jersey Section, at Dennis Hotel, Atlantic City. Secretary, A. F. Pleibel, District Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

Oct. 29–Nov. 1—Florida Section, at Cherry Plaza Hotel, Orlando. Secretary, John B. Miller, Director, Div. of Water Supply, Bureau of San. Eng., State Board of Health, Box 210, Jacksonville 1.

Nov. 1–3—Chesapeake Section, at Emerson Hotel, Baltimore, Md. Secretary, Carl J. Lauter, 6955—33rd St. N.W., Washington, D.C.

Nov. 13–15—North Carolina Section at George Vanderbilt Hotel, Asheville. Secretary, T. Z. Osborne, Asst. Director of Public Works, Box W-2, Greensboro.

OTHER ORGANIZATIONS

Oct. 4–6—North Dakota Water & Sewage Conference, Gladstone Hotel, Jamestown, N.D.

Oct. 8–12—WPCF, Milwaukee, Wis.

Oct. 16–20—ASCE, Statler-Hilton Hotel, New York, N.Y.

Oct. 17–20—Eastern Water Co. Conference, Atlantic City, N.J.

Oct. 19–21—National Society of Professional Engineers, Hotel Roanoke, Roanoke, Va.

Oct. 23–28—First Inter-American Congress of Chemical Engineering, San Juan, P.R. Write: Secretary, Institute of Chemical Engineers of Puerto Rico, Box 47, Rio Piedras Sta., P.R.

Nov. 13–17—APHA, Cobo Hall, Detroit, Mich.

Nov. 26–Dec. 1—ASME Winter Annual Meeting, Statler-Hilton Hotel, New York, N.Y.

Nov. 27–Dec. 1.—28th Exposition of Chemical Industries, Coliseum, New York, N.Y.

SHORT COURSES

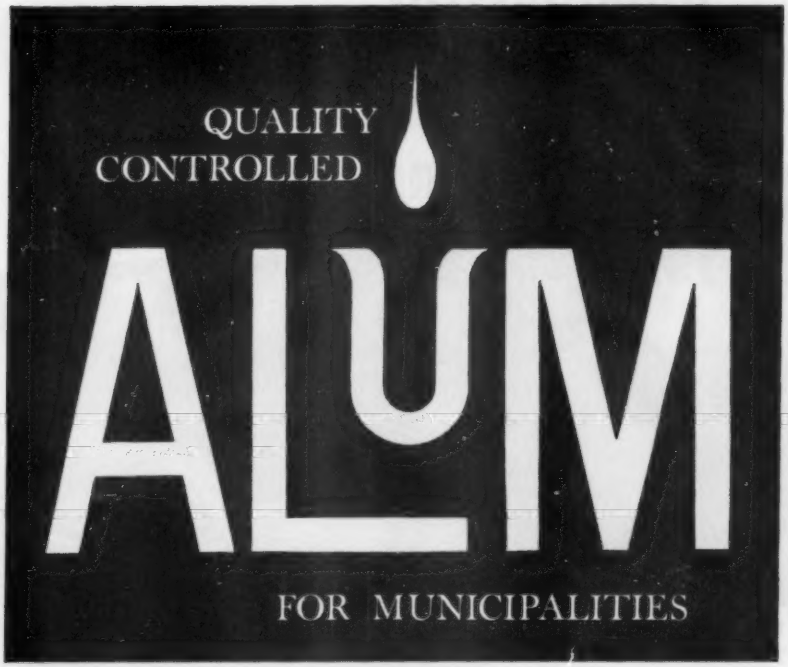
Oct. 16–27—Training course on "Plankton Identification and Control," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional director).

Oct. 23–27—10th Annual Water Works Management Short Course, sponsored by the Illinois and Indiana sections, AWWA, at Allerton House, Monticello, Ill. Write: Short Course Supervisor, 116B Illini Hall, Champaign, Ill.

Nov. 6–10—Training course on "Radioactive Pollutants in Water," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Nov. 13–17—Training course on "Radionuclides in Water," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Dec. 4–15—Training course on "Chemical Analyses for Water Quality," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).



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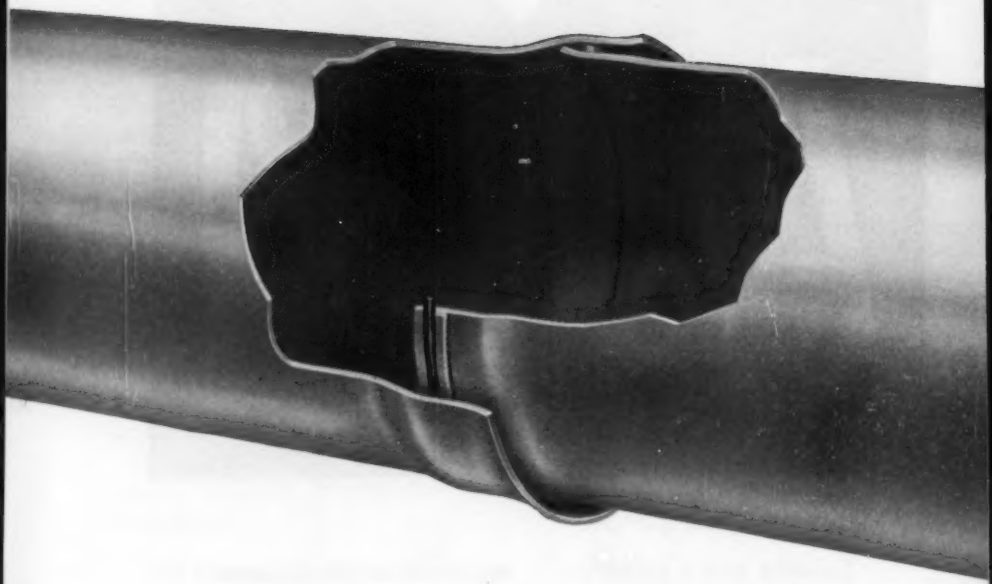

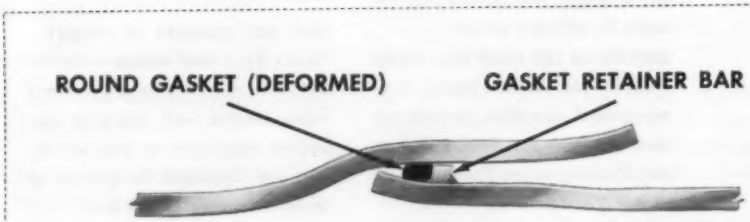

SECTION

Introducing Bethlehem's Bell-and-Spigot Joint, with Gasket

Here's a joint that promises new ease and speed of installation, added to the many well-known advantages of *steel* pipe.

We make it in diameters from 24 in. through 120 in., but if you have something a little smaller or larger in mind, let's talk it over.

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As with all steel pipe, every single 40-ft length undergoes a hydrostatic test well in excess of the design working pressure.

If you're thinking about installing a large-diameter water main, let us give you more information about our new Bell-and-Spigot Pipe. We suggest that you have a talk with the people at the Bethlehem sales office nearest you.

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... Economy
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Engineers: Consoer, Townsend & Associates
Mechanical Contractor: George A. Bass Construction Co.

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Ask your qualified Bailey Engineer to help you plan your water works expansion program. W-4.5

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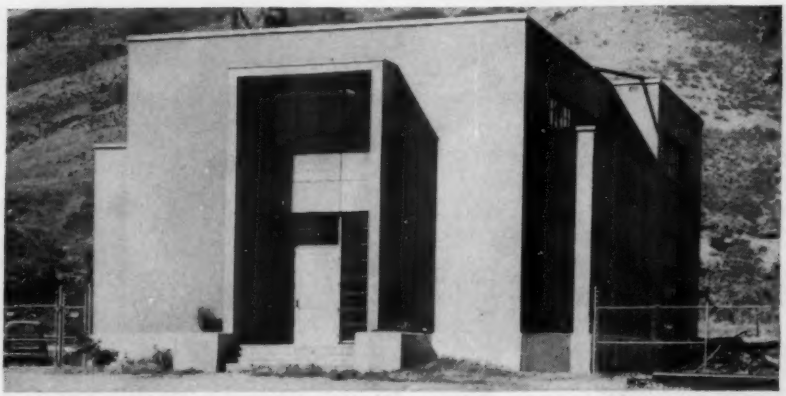
BAILEY METERS

At Golden, Colorado

Hagan Coagulant Aid raises plant throughput by 43%



Water plant at Golden. Main water source is Clear Creek, a fast-flowing mountain stream.

Quick Case History—reading time 57 seconds

THE PLANT: Golden is a growing community, with a rapidly expanding industrial district. The water plant serves some 8,500 people, and must deal with the very turbid water of Clear Creek, which falls an average of 115 feet per mile. The water is first piped to a settling pond, then to a clarifier. Next, filtration, and then to the clear well.

THE PROBLEM: The water carries mine drainage, mud, silt, color and algae, so that, with the best of coagulation possible with lime and alum, turbidities of 20 ppm on top of the filters were not uncommon. Filter runs were short, and plant efficiency hard to maintain.

THE SOLUTION: The use of a coagulant aid was indicated, so an investigation of all available materials was made. Jar tests were used and after four months, the product that seemed to be best was Hagan Coagulant Aid No. 2. Next step was a plant trial, which confirmed laboratory findings.

RESULTS: Turbidity on the filters was reduced to 3 ppm, with zero turbidity after filtration. Plant throughput was increased from 1,500,000 to 2,200,000 gallons per day and backwashing was reduced. Over-all plant operating efficiency has increased by 97 percent. Since Hagan Coagulant Aids are effective over a wide pH range, treatment adjustments are rarely necessary.

THE PRODUCT: Hagan Coagulant Aids are non-toxic, easy to handle, and produce large, tough floc that speed settling time. The Aids are easy to feed, either dry or in slurry form, and are completely safe for use with drinking water. For more information on Hagan Coagulant Aids, write or phone the address below. **Ask for Bulletin HSP-919.**

HAGAN

CHEMICALS & CONTROLS, INC.

HAGAN CENTER, PITTSBURGH 30, PA.

HAGAN DIVISIONS: CALGON CO. • HALL LABORATORIES • BRUNER CORP.

Adaptable

Tailor-made CONCRETE PRESSURE PIPE being installed at a southern power company.

Concrete Pressure Pipe

TAILOR-MADE TO SPECIFICATIONS

For pumping, treatment or industrial plants, concrete pressure pipe can best solve construction problems. No need to build the structure around the limited flexibility of standard fittings. Tailor-made to specific requirements, concrete pressure pipe meets the most exacting demands of entrance or exit into structures; it makes accurate connection with facilities of the building without field cutting or other makeshift expedients.

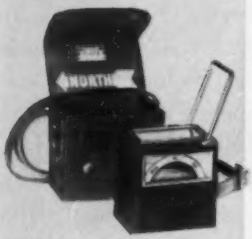
Concrete pressure pipe is also tailor-made to operating conditions, with a variety of designs to assure the most efficient pipe for specific purposes at the most economical cost.

In addition to its adaptability, concrete pressure pipe offers trouble-free service, sustained high carrying capacity and negligible maintenance requirements throughout a remarkably long and useful life.

WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street • Chicago 1, Illinois



"Only The Best"

For ordering dependable and proven pipe line equipment, consult your latest Pollard Catalog #27.

Included in the #27 Catalog, and displayed on this page, are the M-Scope Transistorized Combination Leak Detector and Pipe Locator, Audio-Scope, Geophone Leak Detectors, T-10 Electronic Box Locator, Aqua Valve Box Locator and Magnetic Dipping Needles for locating service boxes.

Hundreds of water departments all over the country are using Pollard "one order" service. You, too, can enjoy the advantages of ordering from the nation's #1 source for dependable pipe line equipment.

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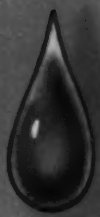
NOW CONTINUOUS REGENERATION WITH FERROSAND* CR FILTER



New . . . Super-Efficient, Super-Economical

WATER CONDITIONING SYSTEM

Removes Iron, Manganese, Sulphide, Organics without Waste Disposal Problems . . . Costly Excess Lime Treatment . . . Settling Tanks and Sludge Removal . . . or Complicated Equipment.

The Ferrosand CR Filter makes possible the following important advantages because of its unique feature of continuous regeneration combined with many improvements in basic filter design:

- Effluent quality usually far superior to conventional methods of iron and manganese removal.
- Much less outage time. No one-hour shut-downs for conventional regenerations — simply backwash and rinse — that's it.
- Extremely low chemical cost. Usually only a trace of permanganate is needed.
- Large water saving — since no intermittent regeneration with brine, permanganate or other chemical.
- No serious waste disposal problem. There is no excess permanganate used — so no problem of disposal of excess permanganate, brine or sludge.

- Higher flow rates — often 3-5 gpm/sq. ft. — resulting in smaller, lower cost equipment and building.
- Manganese removal by simple, straight-thru filtration. No excess lime treatment with settling tank, sludge removal, filter and pH stabilization.

Pressure or gravity systems . . . for manual or automatic operation . . . are available. Your present filter system can be converted at LOW COST.

WRITE OR TELEPHONE FOR FURTHER INFORMATION. WE WILL REFER YOU TO INSTALLATIONS WHERE THE SUPER-ECONOMY AND SUPER-EFFICIENCY OF THE FERROSAND CR FILTER HAVE BEEN UNMISTAKABLY ESTABLISHED.

HUNGERFORD & TERRY, INC.

CLAYTON, NEW JERSEY, U.S.A.

Specialists in Water Conditioning for over 50 years

(A representative will call on request.)

*Patent applied for. License available to qualified manufacturers.

Convert your chlorine system to a system that watches itself, monitors its own results. Conversion is easy with Wallace & Tiernan Automatic Alarms. These dependable warning devices aid in overall operating efficiency . . . give you the final assurance that your system is operating properly, that your water is safe. And these alarms are flexible enough to tie in with any physical layout, any type of signal.

W&T Alarms warn of any deviation from desired performance. You get audible or visible warnings, at or remote from the chlorinator. Alarms warn you of dangerous pressure increases, lowered or exhausted chlorine supply, malfunctions in auxiliary equipment, and other hazards. And, to keep your system "on beam" at all times, alarms show residuals outside pre-set limits.

With automatic alarms by Wallace & Tiernan you avoid dangerous underchlorination and wasteful overchlorination. You save man-hours for more efficient use of personnel.

For more information, write Dept. S-143.05

WALLACE & TIERNAN INCORPORATED
25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

W&T LIME SLAKER SAVES YOU HIDDEN WATER COSTS

Now you can stop paying freight on water. The W&T Paste-type Lime Slaker lets you buy unslaked lime—lets you slake it in your own plant completely, continuously, conveniently.

Wallace & Tiernan's Lime Slaker works with a constant paste slurry, controlled by a torque-actuated water valve. Slaking is complete in 5 minutes, water to lime ratio only 2:1. And the W&T Slaker needs no pre-heating, no insulation. You get a smaller, more compact slaker. The 1000 lb./hr. model occupies less than 6 ft. x 2 ft. of floor space; the 8000 lb./hr. model, less than 46 sq. ft.

Many other fine points too. There's no splash or splatter. Grit removal is completely automatic . . . lime wastage nil.

With the W&T Lime Slaker, you slake lime in your own plant . . . save on freight.

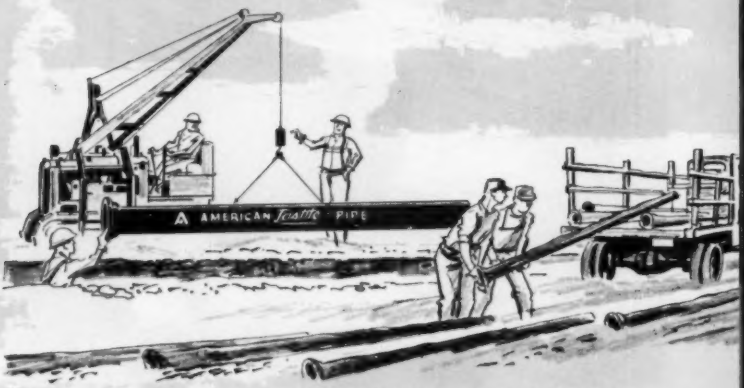
Write for information, Dept. M-58.05.

WALLACE & TIERNAN INC.

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

PIPE

The 100 largest cities in the United States, surveyed recently, have more than 95,000 total miles of water mains — more than 90% of which is cast iron pipe!



DO YOU KNOW that when larger distribution mains are needed, the smaller mains can be reclaimed for years of additional service . . . if they are cast iron? In Reading, Pa., for example . . . seven miles of cast iron pipe was taken up and relaid — saving about $350,000. Rarely, if ever, is composition pipe taken up and re-used.

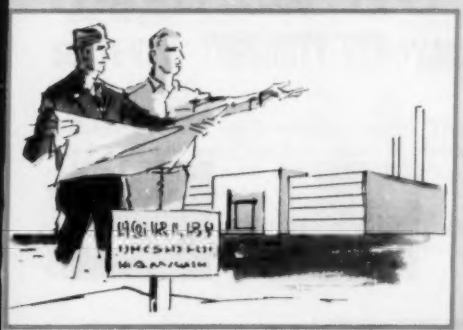
DO YOU KNOW that the AMERICAN Fastite Joint requires no calking? Its only joint component is a dual hardness, easily-inserted, double-sealing rubber gasket. A minimum of labor and equipment is needed to install Fastite pipe . . . and the extra minutes saved soon total up to additional dollars saved in installation costs.

*Patent applied for

FACTS

DO YOU KNOW that cast iron pipe is designed to withstand expected water hammer shocks which can burst weaker mains? In tests, it required 3,400 psi water pressure to burst 6" Class 150 AMERICAN pipe. Composition pipe of similar size and class failed at 770 psi.

DO YOU KNOW that industry requires large volumes of water... and it must be economical? For most new industrial plants, water is the most important natural resource. In the long run, cast iron pipe delivers water cheapest of all.

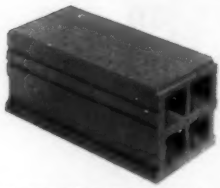


AMERICAN CAST IRON PIPE CO.
BIRMINGHAM ALABAMA

Leopold....

ONE SOURCE, ONE RESPONSIBILITY

WATER PURIFICATION AND FILTER PLANT EQUIPMENT



GLAZED TILE FILTER BOTTOMS

For more than forty years, Leopold has been serving municipalities with time-tested products, technical "know-how" and filter plant design experience. Now you can specify Leopold for the entire job, whether it be for rebuilding or adding plant capacity. Depend on Leopold's careful handling to produce an effectively engineered operation complete with dependable Leopold products, from "top to bottoms." Write for complete information on any of the products illustrated, to the F. B. Leopold Company, Inc., 227 South Division Street, Zelienople, Pennsylvania.

Leopold also manufactures flash and vertical shaft paddle mixers, samplers and sampler tables, orifice box solution feeders and other accessories.

RUBBER-SEATED BUTTERFLY VALVES

FIBERGLASS HOPPERS AND SOLUTION CHAMBERS

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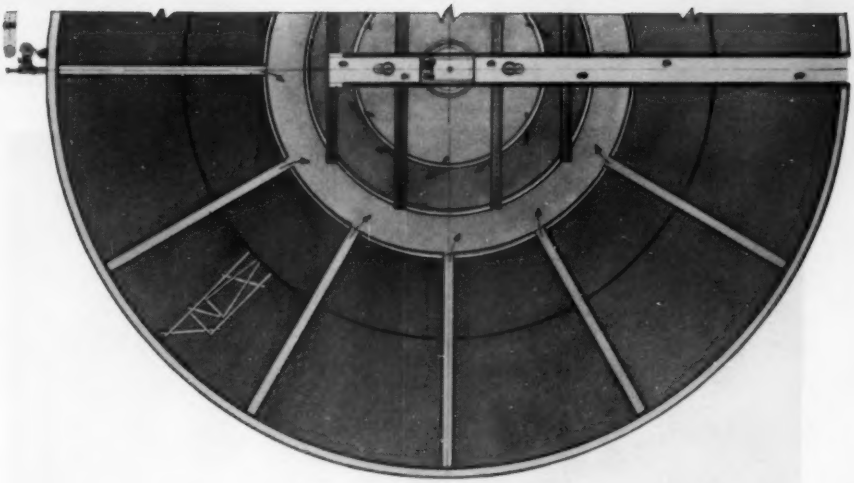
ROTARY SURFACE WASHERS

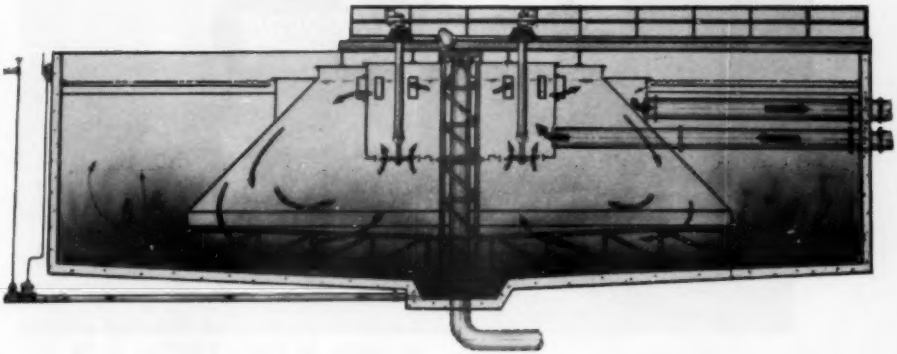
DRY CHEMICAL FEED MACHINES

FILTER OPERATING TABLES AND PANELS

Leopold **F. B. LEOPOLD CO., INC.**

Zelienople, Pa.





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Four or six to one (or even ten to one) internal recirculation for ultimate in particle contact.*

Accelerated chemical reaction and flocc formation for maximum clarification.

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Wide range of sizes and capacities for circular or square basins.

**Where controlled, lesser amounts of contact with the previous precipitate are desired, refer to Walker Process S & R Series Clariflows designed with outside, pumped slurry return.*

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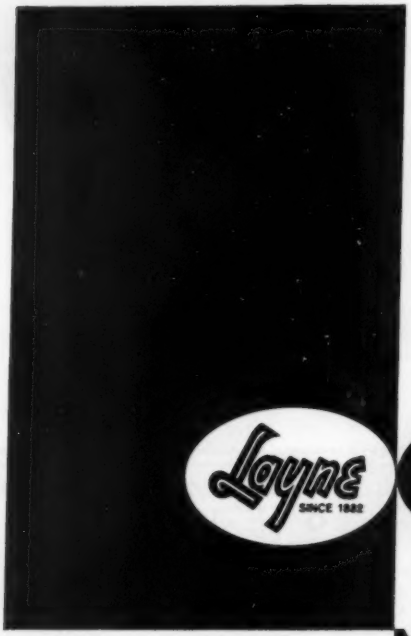

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Write for Layne Service Bulletin 100.

LAYNE OFFERS COMPLETE WATER SERVICE: Initial Surveys • explorations • recommendations, site selection foundation and soil-sampling • well drilling • well casing and screen • pump design, manufacture and installation • construction of water systems • maintenance and service • chemical treatment of water wells • water treatment—all backed by Layne Research • Layne services do not replace, but coordinate with the services of consulting, plant and city engineers.

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Crystal-clear water... and every drop free of germs, algae, and fungi. HTH releases effective, dependable chlorine that sanitizes new pipe lines, protects wells and reservoirs, too. Comes in either free-flowing granular or convenient tablet form. Packed in new, easy-to-handle 3¾-lb. plastic bottles, 35-lb. pails and 100-lb. metal drums. Write for literature, to: OLIN MATHIESON, Baltimore 3, Md.

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9311 CHEMICALS DIVISION Olin

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***B-I-F** laboratory control...*
more efficient water treatment
for less money!

ONE MAN CONTROL — From a single console in laboratory, the best qualified man (the plant chemist or chief operator) now has instant fingertip control over plant through-put, chemical additions, and filter backwash. This simplifies and improves process supervision . . . releases other manpower for more productive assignments.

MORE EFFICIENT FILTRATION — Auto-Central backwash control . . . eliminates over or under washing and upset filter beds . . . allows key-man to make immediate, corrective adjustments over entire filtration and treatment process.

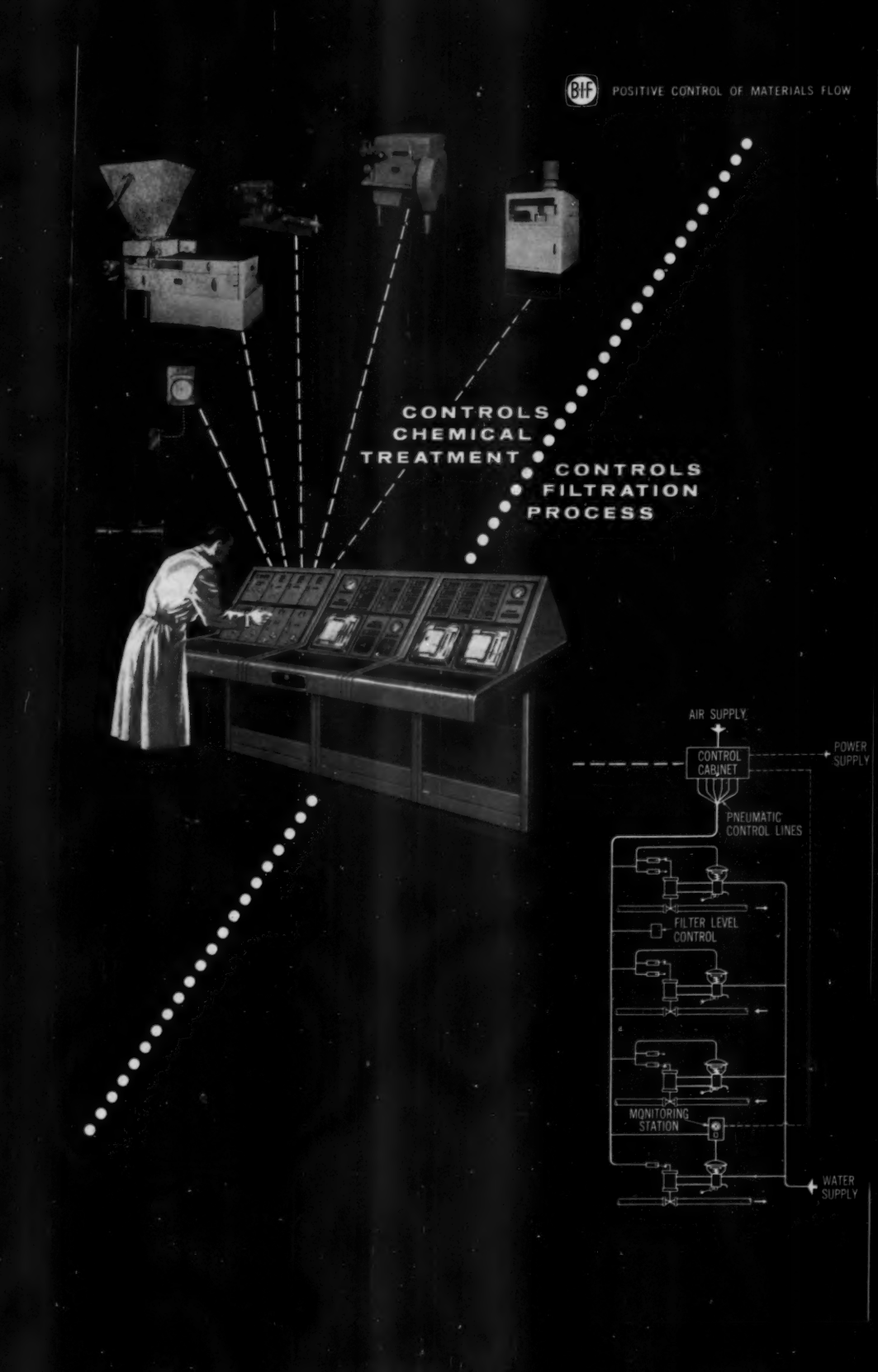
REDUCED COSTS — Overall plant construction costs reduced 15% to 20% by eliminating structures over filters. Chemical feeders located for straight-line process flow . . . protects floc, improves settling, provides longer filter runs. Remote location of feeders reduces maintenance cost by removing chemical dust problem from office and laboratory.

ANOTHER B-I-F 1st! — Since the introduction of its Venturi Tube, 74 years ago, B-I-F has continuously developed new products and concepts in the municipal water treatment field. Today Laboratory Control makes your municipal bond dollar go farther by increasing filtration efficiency at lower cost.

REQUEST new Bulletin 2-1.20-1. Write **B-I-F Industries, 365 Harris Avenue, Providence 1, Rhode Island.**

B-I-F **Industries**
A DIVISION OF THE NEW YORK AIR BRAKE COMPANY
METERS • FEEDERS • CONTROLS / CONTINUOUS PROCESS ENGINEERING

BIF POSITIVE CONTROL OF MATERIALS FLOW



ION EXCHANGE APPLICATIONS

A *Nalco*® Expert Answers Questions About an Economical, Efficient Method of Municipal Water Demineralization

F. K. Lindsay, Product Manager, Ion Exchange Department

The use of ion exchange resins to reduce hardness of municipal water supplies has become more and more common as an ever increasing number of communities have come to realize the benefits of this modern, economical method of water softening. Here are a few of the more common questions answered for you by F. K. Lindsay, Nalco expert on municipal ion exchange applications.

Question: Can ion exchange softening be used to reduce hardness of any municipal water supply?

Answer: Yes, though ion exchange may be more economical under some conditions than under others. For example, when quantity demands are great, high bicarbonate waters are sometimes more economically treated with lime. When only moderate demands are made on the system, however, ion exchange processes are not only simpler, but less expensive, and are particularly suited to intermittent operation. Whether or not ion exchange can be used to advantage in a given system can be determined from a detailed analysis of that system—an analysis which can be made by a Nalco ion exchange specialist upon request.

Question: Do ion exchange softening processes work efficiently on water supplies containing iron?

Answer: Ion exchange can be used to treat iron bearing water. However, it is often desirable in such cases to first remove the iron by an oxidation and filtration process, so that both the water passed through the resin beds, and the blending water used for control of hardness at the mains, are iron free. The city of Pella, Iowa, has such a system, where iron removal and ion exchange softening are carried on automatically to keep the hardness level at no more than 5 grains per gallon. Ground water is pumped through an aerator and passed through gravity sand filters, which remove oxidized iron. Part of this iron-free water flows to open gravity beds containing Nalcite® HCR-W® cation exchanger and the balance of the filter effluent is blended with the exchanger effluent to maintain exact hardness control. The resin beds are regenerated at a low salt dosage, and automatic titrators control the point at which the regeneration takes place. When the storage tanks and stand pipe are full, the well pump stops and the plant remains idle until more water is needed. If the iron removal plant were not used, the ion exchange beds would require heavier salt dosages and periodic cleaning.

MUNICIPAL WATER SYSTEMS

Question: Can ion exchange be used to lower cost when lime-soda treating?

Answer: Yes. Water now requiring large quantities of soda ash can be treated economically by eliminating soda ash and following lime-treatment with ion exchange. This process is used by the Village of LaGrange, Illinois, where high sulfate hardness water is treated first with lime to reduce carbonate hardness and remove iron, and the lime treater effluent (at a 20-grain hardness level) is filtered, and passed up-flow through Nalcite HCR® cation exchange open gravity resin beds. The "Zeolite" softened water is then blended with filtered lime-treater effluent to maintain hardness at a 5 grain per gallon level. Salt consumption amounts to 0.25 pounds per kilograin of hardness removed from the filtered lime-treated water.

Question: Many municipalities draw their water from several wells. How can ion exchange be used in such cases?

Answer: If the water supply does not contain constituents that will foul ion exchange resin beds, automatic water softeners and blending controls can be placed at each source. Operation is automatic—water flowing from each well is reduced in hardness to the desired levels, and contact meters determine the need for regeneration.

Question: Can sea water be used to regenerate ion exchange resins?

Answer: Yes. Nalcite HCR or Nalcite HCR-W cation exchangers can be regenerated with sea water to produce capacities of 15,000 to 18,000 grains per cubic foot. However, sea water must be adequately filtered, and usually chlorinated, to prevent contamination of resin beds. The sea water is pumped up-flow through the resin beds, similar to a backwashing process, and the flow is then reversed to pass the sea water down-flow through the bed. About fifty gallons of sea water per cubic foot of resin bed will provide effective regeneration. The city of Jacksonville Beach, Fla., operates a plant of this kind to soften a well-water supply, using pressure-type equipment which is automatically regenerated with sea water on a gallonage basis.

Brine wells can also be used to regenerate resin beds if the salt content is sufficiently high to provide effective capacities. A two per cent or greater concentration is desirable, although wells containing as little as 0.75 per cent NaCl have produced about 8000 grains capacity per cubic foot.

Question: What are the advantages of using Nalcite ion exchange materials?

Answer: Quality resins and expert technical assistance on ion exchange. Nalcite ion exchange resins are produced by the Dow Chemical Company for Nalco Chemical Company, and are available from leading water conditioning equipment manufacturers. These resins are produced in carefully controlled manufacturing processes, during which small, weak, and cracked beads are virtually eliminated. The result is a water softener made up of tough, long-lasting ion exchange resin beads. And, as with other Nalco products, Nalco experts are at your service, to help you analyze and solve your water conditioning requirements. For information about water conditioning with Nalcite ion exchangers, write to Nalco for Bulletin Z-5.

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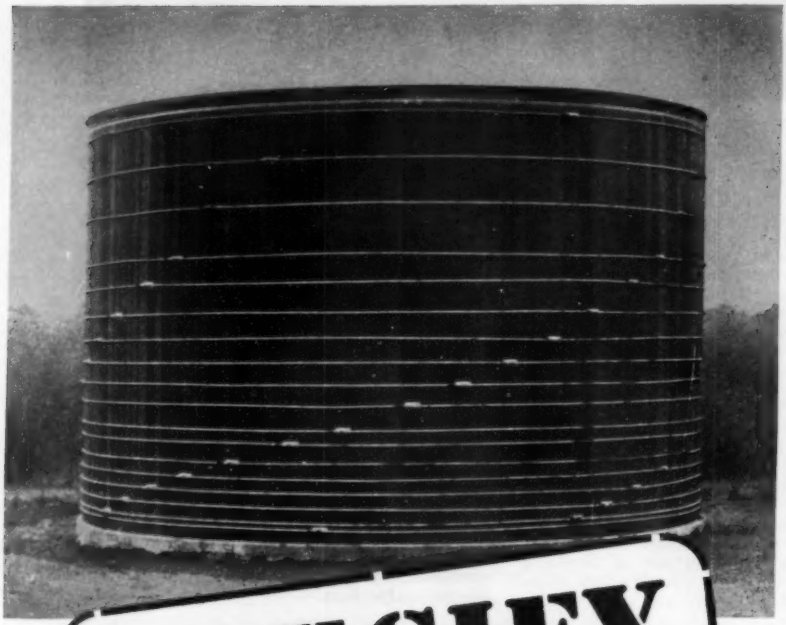

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HANDLE WITH CARE

That's the treatment your water well gets when you call Halliburton for Acidizing Services.

CARE in helping you select the proper type and strength of acid.

CARE in placing the acid solution at the proper rate and pressure.

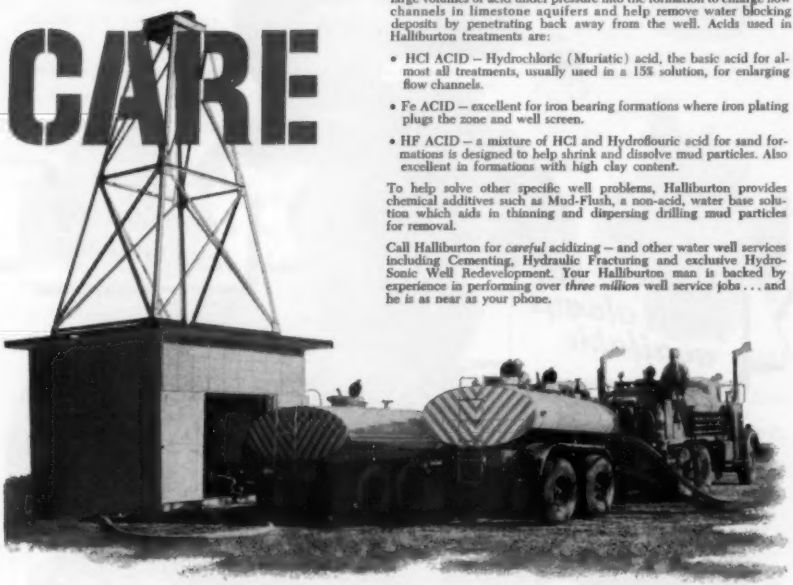
CARE in performing a truly professional well treatment all around — *and at a reasonable price!*

This care and attention is part of the service when you or your contractor deal with Halliburton. Halliburton Acid Treatments inject large volumes of acid under pressure into the formation to enlarge flow channels in limestone aquifers and help remove water blocking deposits by penetrating back away from the well. Acids used in Halliburton treatments are:

- HCl ACID — Hydrochloric (Muriatic) acid, the basic acid for almost all treatments, usually used in a 15% solution, for enlarging flow channels.
- Fe ACID — excellent for iron bearing formations where iron plating plugs the zone and well screen.
- HF ACID — a mixture of HCl and Hydrofluoric acid for sand formations is designed to help shrink and dissolve mud particles. Also excellent in formations with high clay content.

To help solve other specific well problems, Halliburton provides chemical additives such as Mud-Flush, a non-acid, water base solution which aids in thinning and dispersing drilling mud particles for removal.

Call Halliburton for *careful* acidizing — and other water well services including Cementing, Hydraulic Fracturing and exclusive Hydro-Sonic Well Redevelopment. Your Halliburton man is backed by experience in performing over *three million* well service jobs . . . and he is as near as your phone.



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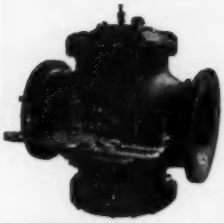
1879—ROSS—1879

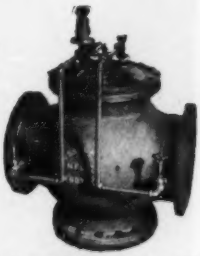
Automatic Valves



ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs

1. Single Acting
2. Double Acting



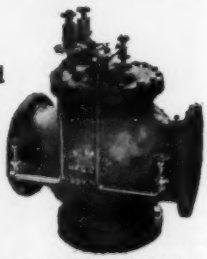
SURGE-RELIEF VALVE

Maintains safe operating pressures for conduits, distribution and pump discharge

REDUCING VALVE

Maintains desired discharge pressure regardless of change in rate of flow

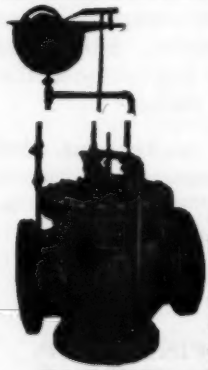
Regulates pressure in gravity and pump systems; between reservoirs and zones of different pressures, etc.



COMBINATION VALVE

A self contained unit with three or more automatic controls

Combination automatic control both directions through the valve.



FLOAT VALVE

Maintains levels in tank, reservoir or basin

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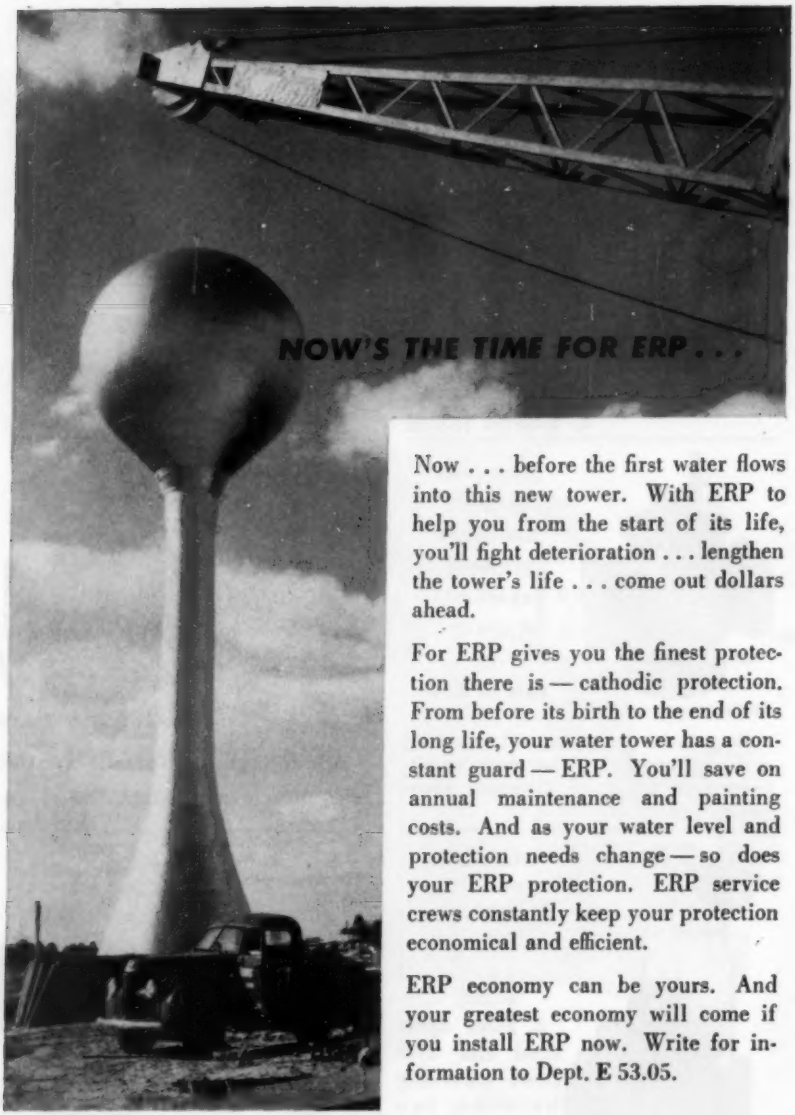

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Planning for National Water Needs

Robert S. Kerr

An address presented on Jun. 5, 1961, at the Annual Conference, Detroit, Mich., by Robert S. Kerr, US Senator from Oklahoma.

I AM particularly pleased to talk with this audience of water men of America about planning for our future water needs. I know that the nation can count on you, as it has counted on you in the past, to advance the science and the service of the water supply industry so that the nation's needs for water can be met.

I sometimes refer to you as "hydronauts" because you are leading us on the way to new frontiers in the field of water resources development, just as our astronauts stand on the threshold of the future exploration of space.

There is a new spirit alive in Washington. For 8 years, progress in water resources development was slowed down or stopped by a policy of "no new starts." Development and use of our water resources for the benefit of all were held to be of less importance than a balanced budget. Now, under the dynamic leadership of President Kennedy, there is a spark of vitality that reaches down through all the agencies of the government. A mighty nation is facing up to the needs and responsibilities in the field of water resources for the first time in almost a decade. We are going to make greater progress in conservation and development of our water resources in the next few years than ever before. AWWA members have performed a great public service in providing good water to our cities and towns and industries in the past, and I am sure that they will meet the challenge of our new goals and aspirations in the future.

Need for Planning

At Detroit, on the shores of the Great Lakes, which contain over one-third of the world's fresh-water supply, one would think that there should be no water problems. Yet, when the recent Select Committee on National Water Resources of the United States Senate made its studies, it found that such was not the case. The committee

was invited to come to Detroit to hold a hearing by one of its most distinguished members, Philip A. Hart, senator from Michigan. We found the same water supply and pollution abatement problems at Detroit as in the other parts of the nation. We found serious pollution problems. We found, at Detroit, as elsewhere, a lack of knowledge as to the effects of pollution on the Lakes. We found conflicting demands for water. Many problems were brought home to us forcefully at our hearings at Detroit. It was the first hearing the committee held east of the Mississippi River. And it was one of the best we had anywhere. It and every other one of the 25 hearings held by the committee pointed to the need for an all-out, coordinated attack on the problems of water resources development. The hearings made it very clear that the efforts of all agencies of the federal government, of state and local governments, and of private industry would be needed if our economy is to be prevented from suffering from shortages of water.

I believe there is just one answer, and it is broad comprehensive planning for water resources development. I have favored this approach ever since I served as governor of Oklahoma during World War II and the immediate postwar years. After seeing the mighty Arkansas and its tributaries ravage our countryside in times of floods, only to dry up in the summer and permit our top soil to be blown to the four winds, I realized the great need for comprehensive water resources development. In Oklahoma today, we are grateful for the developments that are now underway on the Arkansas River as a result of our planning. The first bill that I introduced, when I went to the United States Senate in 1949, was for the purpose of creating an interagency study commission for the Arkansas, White, and Red River basins. This study covered watersheds of 180,000,000 acres, including all of Oklahoma and parts of seven other states. The report on that study was completed after more than 5 years of effort, and it represents one of the pioneering efforts in planning for the comprehensive, coordinated development of the land and water resources of our large river basins.

We now have under way a broad program of conservation of our land, wood, and water. As a matter of fact, I used those words—"Land, Wood and Water"—for the title of a book, published in 1960, in which I tried to give credit to many people who contributed to the dream which is fast becoming a reality in Oklahoma.

Select Committee Report

But you hydronauts will be more interested, I am sure, in the recent report [1, 2] of the Senate Select Committee on National Water Resources, on which I had the privilege of serving as chairman. Between May 1959 and January 1961, the select committee undertook one of the most comprehensive studies ever made of the water resources of the United States. AWWA was represented at several of the hearings, and its studies on water resources policy and on various technical aspects of municipal water supply were made available to the committee. I hope that all AWWA members have seen the report of the committee. I am told that so far more than 150,000 copies of the committee's studies and report have been distributed throughout the country to people who have asked for them.

After review and study of the background material obtained by this massive effort, the committee found that the margin between the nation's water supply and the demands for water for all purposes is shrinking rapidly. Withdrawals of water now are estimated at about 300 bgd. On the basis of medium projections of population increase and economic growth, which I consider are likely to be exceeded, the committee was told that by 1980 demands on the nation's water resources will be doubled, and that they will triple by the year 2000. If the nation's growth rate is greater than the medium estimates, as I am almost positive they will be, these increased demands for water will come upon us at an even earlier time.

Future Efforts

All the estimates are based on assumptions that there will be relatively little change in the present methods of water use and water waste. Under the assumptions made, the committee concluded that five major categories of effort would need to be intensified in the future, if prospective demands are to be met in such a way as not to inhibit national or regional economic growth:

1. We need to regulate further our streamflow through the construction of surface water reservoirs and through better watershed management.

2. We must improve the quality of our streams through more adequate pollution abatement or, as I would prefer to call it, better water quality management.

3. We must make better use of potentialities for underground storage of water.

4. We must increase the efficiency with which water is used through such methods as elimination of wasteful practices in irrigation, improved sewage treatment methods, recirculation, and substitution of air for water cooling in areas of potential water shortage.

5. We must give greater support to research programs leading to cheaper methods of desalting, weather modification, and other means of increasing water availability and yield.

Increase in Water Use

All of the objectives require planning now for future action. Figure 1 shows how the total requirements for water by the year 2000 will be approaching the equivalent of the total streamflow in the United States, exclusive of Alaska and Hawaii.[1, 2] As of 1954, the streamflow was about 1,100 bgd; demands for withdrawals that year were about 300 bgd, or roughly 27 per cent of streamflow. The withdrawals, as shown in the figure, are divided into withdrawals for irrigation, municipal, industrial, and steam electric-power cooling, with the withdrawals for each of these purposes and the total of all divided into consumptive and nonconsumptive uses.

The estimates of water needs for the same purposes are also shown in the figure for the years 1980 and 2000. Along with the increased water demands, a reduction in streamflow is shown resulting from depletions by conservation of wildlife and for watershed improvement. This is shown by the bracketed portion of the "water supply available" bars. Thus we have a water demand rising steeply against a water supply which is being reduced by these factors.

Now the convergence of these two factors need not be a cause for alarm *if* we will begin to take the necessary action now. We must see that the

necessary steps are taken to provide for holdover storage to even out the flow of our streams so that water will be available when needed. We must undertake measures to improve our water quality management in order to permit water to be used over and over again.

The select committee also gave attention to the fact that, in addition to

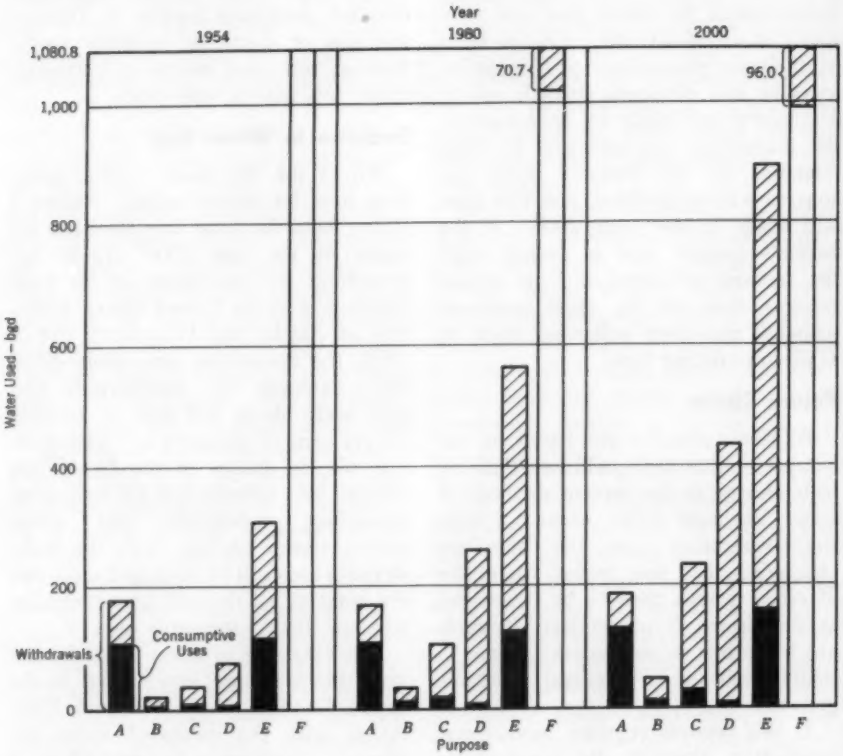

Fig. 1. Water Withdrawals and Consumptive Uses: Diversions and Depletions From Streams and Other Sources

The letters represent: A, *irrigation;* B, *municipal use;* C, *industrial use;* D. *steam electric-power cooling;* E, *total withdrawals and consumptive uses; and* F, *water supply available. Except for the quantities consumed, the same water can be withdrawn and reused many times, provided its quality is maintained. The value 1,080.8 bgd on the ordinate is the average flow that can be sustained under 1954 conditions. This is the maximum low flow before depletion from use but after estimated evaporation losses from added reservoir capacity. The bracketed portion of the "water supply available" bars for the years 1980 and 2000 represents the increase after 1954 in onsite depletions by additional swamps and wetlands for fish and wildlife and by watershed improvement programs. Onsite depletions are not shown for 1954 because they have already been subtracted from average flow.*

water for consumptive uses and depletions, tremendous quantities of water will be needed in our flowing streams for other purposes. These include: hydroelectric-power production, navigation, recreation, fish habitat, and pollution abatement, or water quality management.

The estimates of the flow requirements for these purposes, prepared by the committee, are shown in Fig. 2.[1,2] The assumption was made that if water requirements for navigation are met, and if water of adequate quality for fish life is maintained, the needs for recreation will be met. The figure

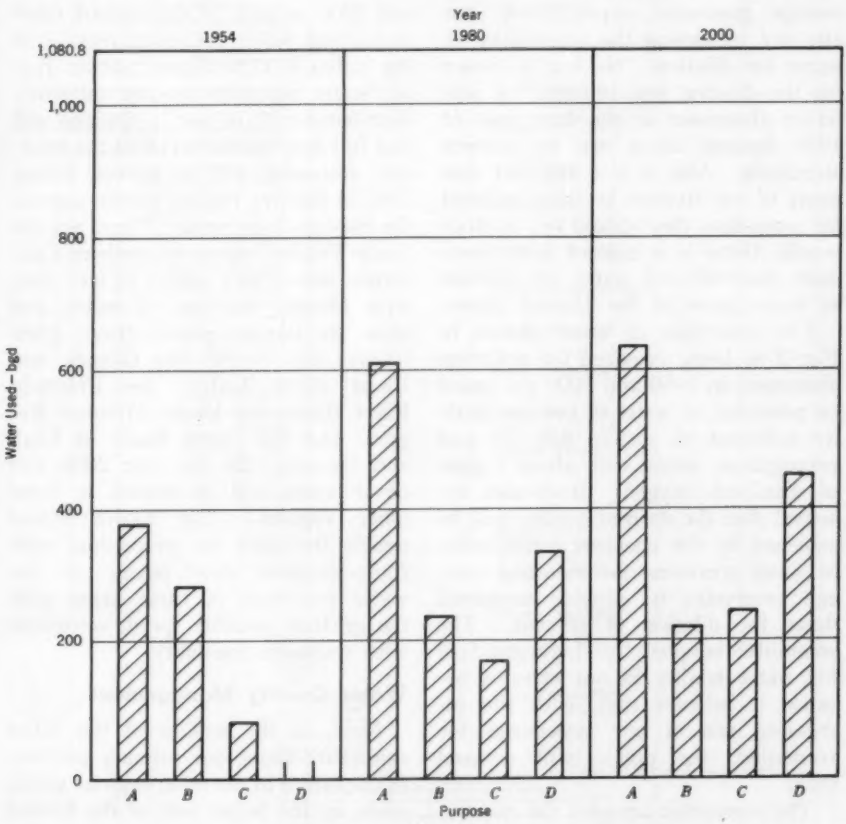

Fig. 2. Streamflow Uses

The letters represent: A, *hydroelectric power;* B, *navigation;* C, *sport fish habitat; and* D, *pollution abatement. The value 1,080.8 bgd on the ordinate represents the average flow that can be sustained under 1954 conditions. This is the maximum low flow before depletion from use but after estimated evaporation losses from added reservoir capacity. No amount has been shown for 1954 pollution abatement, because there were no standards for that year.*

shows most significantly the needs for additional flows to maintain the water quality of our streams. Even with the ultimate in sewage treatment facilities, it is a fact that a certain amount of water will be required for dilution of the effluent. Thus, as the nation's population and industry grow, there will be need not only for increasing sewage treatment expenditures, but also for increasing the availability of water for dilution. No bar is shown for the dilution requirements for pollution abatement in the base year of 1954 because there are no current standards. And it is a sad fact that many of our streams are now polluted far more than they should be; in other words, there is a lack of both treatment facilities and water for dilution in many parts of the United States.

The quantities of water shown in Fig. 2 as being required for pollution abatement in 1980 and 2000 are based on provision of water of average quality sufficient to sustain fish life and propagation, water with about 4 ppm of dissolved oxygen. It is also assumed that the desired quality will be achieved by the cheapest combination of waste treatment facilities and storage reservoirs to provide sustained flows for dilution of effluent. The committee adopted this high standard for water quality in our streams because it believes that, with the increasing use of our waterways for recreation, the public will demand them.

The committee accepted the requirements for water quality management as being controlling, even though larger amounts of water are shown to be needed for hydroelectric-power generation. With the construction of the needed reservoirs, there will be many more opportunities to develop hydroelectric power in the future, and I expect a continued increase in hydroelectric-power installations. As there are other sources of electrical energy, however, the needs for hydropower generation were not assumed to be a controlling demand for water.

Figure 3 shows how well we can meet our water requirements in 1980 and 2000 in each of the various river basins and water resources regions of the nation.[8] The figure shows that our water resources are not uniformly distributed with respect to demand and that full development of all of the available resources will be needed before 1980 in the five regions shown nearest the bottom of the scale. These are the South Pacific Region, or southern California, where, as a matter of fact, they have already run out of water and have to import water from other basins; the Upper Rio Grande and Pecos River basins; the Colorado River Basin; the Upper Missouri Region; and the Great Basin of Utah and Nevada. By the year 2000, full development will be needed in three other regions. The figure shows clearly the need for proceeding with comprehensive development of the water resources of these areas with the greatest possible speed, consistent with economic feasibility.

Water Quality Management

Now, as the studies of the select committee show, our primary problem of the future in the other regions which make up the larger part of the United States will be that of water quality management. There is just no way around it. We will have to devote more and more of our streamflow resources in this country to carrying away pollution, and that is why, in the present session of the Congress, we

are going to take action which will provide for a new vigor in our federal programs of streamflow pollution abatement. To this end, I am actively promoting legislation in the Congress during 1961 to tackle the problem head on. My proposal, which was introduced as Senate Bill 120, not only

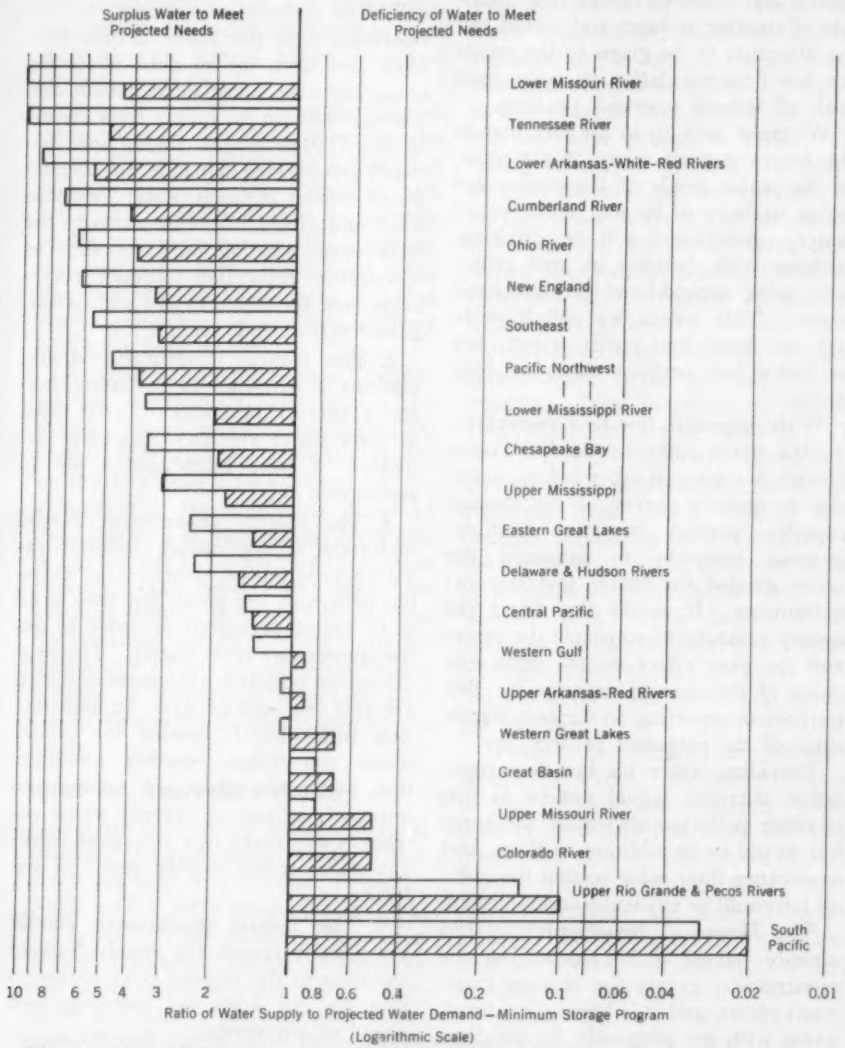

Fig. 3. Ratio of Maximum Obtainable Supply to Minimum Flow Requirement for the Years 1980 and 2000

Open bars represent the year 1980; striped bars, the year 2000.

would increase federal support for the construction of sewage treatment plants, but would also authorize a much more intensive program of research and development of new methods of treating sewage, and would call for attention to be given to the needs for low-flow regulation in connection with all federal reservoir projects.

We must face up to the fact that in the future a great many, if not most, of the water needs of the nation are going to have to be met with reused water. Americans will be drinking, cooking with, bathing in, and otherwise using second-hand or third-hand water. This means we will have to use our water and purify it not once or twice but perhaps three or four times.

With respect to low-flow regulation, my bill would authorize the US Public Health Service and other federal agencies to make a survey of the storage capacity needed in any multiple-purpose reservoir to impound the water needed for future low-flow requirements. It would also direct the agency planning to construct the reservoir to give effect to the economic value of the storage capacity for this purpose in reporting on the cost-benefit ratio of the proposed project.

Providing water for low-flow regulation purposes would not be in lieu of other pollution abatement measures but would be in addition to them, and to enhance their value so that the overall job could be efficiently accomplished.

The House of Representatives has already passed a bill increasing the construction grants for sewage treatment plants, and it is being considered, along with my proposals, by the Senate. I am confident that there will be affirmative action on this legislation in the present session of Congress.

Committee Recommendations

The select committee made certain recommendations which deserve repeating here:

1. The federal government, in cooperation with the states, should prepare and keep up to date plans for comprehensive water development and management for all major river basins in the United States, taking into account prospective demands for all purposes served through water development and giving full recognition to the nonrevenue-yielding purposes such as streamflow regulation, outdoor recreation, and the preservation and propagation of fish and wildlife.

2. The federal government should institute a program of matching federal grants to the states to assist them in their water resources planning activities. I have introduced a bill to accomplish this.

3. The federal government should undertake a coordinated, scientific research program on water. Our existing programs are good, but they need to be better organized in order to get the answers we need sooner. The provisions on pollution abatement research are just one part of this. In addition, new legislation is needed for saline-water conversion, weather modification, and many other new methods to improve our use of present water resources and make new resources available to meet the soaring needs of the future.

4. The federal government should periodically review the supply-demand situation in the various river basins so that we can keep our planning well ahead of our needs.

The committee also made a number of recommendations on subjects such as regulation of flood-plain use, in-

creased study of areas of emerging acute water problems, studies of the needs for reserving the sites for major storage reservoirs to achieve the river control that will be needed, and additional public hearings in connection with federal water resources undertakings.

A number of these recommendations have already been proposed by the administration. With the action that is being taken by the President, and with the legislation that is already under consideration in the Congress, the year 1961 gives promise of being the best year for the future of water resources in this country that we have had for a long time.

As chairman of the Senate Committee on Aeronautical and Space Sciences, I have recently been brought face to face with the problems caused by the long lead time required for development of space vehicles. Lack of this lead time is now costing us dearly in our efforts to match Soviet Russian exploits. The problems of lead time are also with us in respect to our water resources problems. We must redouble our efforts now if the necessary actions in the water resources field are to be completed in advance of the needs.

Need for Aggressive Action

We are surrounded by evidences of the compelling necessity for more vigorous and aggressive action. Recently, I saw a UPI story from Marion, Ind., a city of 38,000 people. Workmen labored through a holiday to complete new wells to end a water crisis. Factories and schools were ordered to remain closed for a day to conserve water. The shortage had developed the previous week when, without notice, the city's wells began running dry, leaving the city virtually without water.

I was appalled recently to learn of the report from USPHS that, for the first 20 weeks of 1961, there were more than 35,000 cases of hepatitis reported in the nation. In metropolitan areas everywhere, the total cases soared to more than twice the number for the same period in 1960. This deadly disease is very tricky to handle because there is no known cure yet. In fact, I am advised that no scientist has ever seen the elusive virus which causes the disease, yet we know that it is a fearful offspring of polluted, filthy drinking water.

Another strong stimulant to more speedy action is the ominous threat of drought. *Time* magazine of May 26, 1961, had an article headed "The West—Dying of Thirst." It reminded us that, while much of the nation was suffering from floods, disaster from drought is building up in vast areas of the Great West. The governor of one state declared, "Our whole state is a disaster area." The danger of fire perils vast areas, both forest and urban. The governor of another state said, "If you haven't got water, you haven't got anything."

Weather technicians and scientists repeatedly warned our select committee that droughts are recurring. These experts established a basis for their predictions that the late 1960's or early 1970's would probably see drought more widespread and acute than that of either the 1930's or 1950's. These facts are somber and constitute a stern warning, yet they need not be the basis for gloom. To be forewarned is to be forearmed.

We are the largest, most powerful nation on the earth. We have an abundance of water for our needs

today and for the foreseeable future. But we must use the lead time available to us to clean up and bring an end to the pollution of this precious liquid of life. We must increase the means of conserving and storing our water to prevent the increasing damage of uncontrolled flood waters and have the abundant water supplies available as needed. We must advance the science and techniques of conservation to insure that abundance of useable water.

Thus we can march triumphantly into the "golden sixties" and the "soaring seventies." We can press forward into a fabulous future unparalleled in dynamic growth and peaceful progress for our country. You AWWA members are part and parcel of this effort. Your brains, experience, and leadership can insure success for your own areas and for our country. I salute you, hydronauts of the sixties, as you successfully strive to construct a more powerful and triumphant nation.

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Progress in Saline-Water Conversion

Task Group Report

A report of Task Group 2770 P—Saline Water Conversion, submitted by Rolf Eliassen (Chairman), Prof. of San. Eng., Massachusetts Inst. of Technology, Cambridge, Mass. Other members of the committee are J. D. Bakken, A. Cywin, L. S. Finch, W. E. Katz, L. Koenig, F. A. Loebel, R. W. Morse, and E. H. Sieveka.

FOR its first effort, the task group has sought to clarify the issue of greatest present significance to the members of AWWA—the utilization of the vast underground reservoirs of brackish waters in North America. Subsequent reports will concern themselves with the conversion of sea water to potable water.

Summary

This report discusses the principles, economics, and future applicability of some of the desalinization or demineralization processes currently being used or investigated, including distillation, electrodialysis, freezing, and solar energy. The present status of demonstration plants and the need for further installations of this nature are discussed.

The extent of brackish-water areas in the United States and Canada has been surveyed by the committee. Of 20,215 municipal water utilities in 50 states and five provinces, 1,066 had raw water with total dissolved solids of 1,000–3,000 ppm, and 31 had water with total dissolved solids in the range of 3,000–10,000 ppm. These values define the principal markets for desalinization and involve the southwestern and north-central parts of the United States, the Gulf of Mexico and Florida coasts, and the prairie provinces of Canada.

The task group emphasizes that on one hand, the premium that communities are willing to pay for good stored water transmitted over long distances will gradually diminish as familiarity with the use of demineralized brackish water becomes more general. On the other hand, the task group warns that saline-water conversion is not the only answer to all hopes for adequate water supplies in the future. Research and development must continue on a broad scale in many other directions, including conservation in agricultural, municipal, and industrial uses of water, the reclamation and reuse of existing water sources, and the search for new sources.

Survey of Brackish Waters

A questionnaire survey has been made of the 50 states and ten Canadian provinces to determine the present extent of public brackish raw-water sources as well as the opinions of design review agencies regarding brackish-water treatment. All of the states and five of the provinces responded to the questionnaire.

The terms "saline" and "brackish" are being used somewhat interchangeably at present. USGS has adopted

a rating system for waters having total solids contents of 1,000–35,000 ppm or more in an attempt to establish an acceptable classification for highly mineralized waters. The first two ratings of 1,000–3,000 ppm and 3,000–10,000 ppm are felt to include the water sources that should be termed slightly and moderately brackish-water supplies. Those brackish-water sources are being used at the present time by municipalities and industry, and will more than likely have to be used to a greater extent in the future.

TABLE 1

Brackish Municipal Water Supplies in the United States

State	Total Number of Supplies	Brackish Water Supplies	
		1,000–3,000 ppm total dissolved solids	3,000–10,000 ppm total dissolved solids
Alabama	365	8	0
Alaska	33	0	0
Arizona	400	112	1
Arkansas	238	4	0
California	940	24* 44†	0
Colorado	257	15	0
Connecticut	145	0	0
Delaware	42	0	0
Florida	779	26‡ 28§	0
Georgia	600	0	0
Hawaii	75	2	0
Idaho	200	0	0
Illinois	923	61	2
Indiana	375	0	0
Iowa	712	143	8
Kansas	460	30	0
Kentucky	no data		
Louisiana	246	12	0
Maine	165	0	0
Maryland	161	1	0
Massachusetts	331	0	0
Michigan	750	20	0
Minnesota	602	59	0
Mississippi	239	3	0
Missouri	495	12	2
Montana	158	32	2
Nebraska	434	0	0
Nevada	45	0	0
New Hampshire	138	0	0
New Jersey	426	1	0
New Mexico	198	3	0
New York	1,071‖	0	0
North Carolina	316	2	0
North Dakota	165	83	5
Ohio	676	29	0
Oklahoma	421	43	7
Oregon	472	1	0
Pennsylvania	1,300	0	0
Rhode Island	45	0	0
South Carolina	153	2	0
South Dakota	250	153	3
Tennessee	300	0	0
Texas	1230	70	0
Utah	no data		
Vermont	190	0	0
Virginia	171	1	0
Washington	1,000	2	0
West Virginia	400	0	0
Wisconsin	570	3	0
Wyoming	78	1	0

* All water utility sources.
† Only one or more of the water utility sources.
‡ Municipal.
§ Housing subdivisions and trailer parks.
‖ Serving 1,737 communities.

From the strict standpoint of conventional chemical quality as measured by the total solids analysis and other common determinations such as total hardness and alkalinity, much of the United States and Canada is presently blessed with ample nonbrackish surface and ground water sources. Table 1 contains a summary of municipal water utilities having raw-water sources with total solids contents in excess of 1,000 ppm, as compared to the total number of water utilities in the United States. Table 2 is the same for Canada.

Twenty-nine of the 50 states—22 east of the Mississippi River—and four of the five reporting Canadian provinces reported that all, or virtually all, of their raw water sources had total solids contents of less than 1,000 ppm. Five states—Colorado, Kansas, Michigan, Missouri, and Ohio—listed 3–7 per cent of their municipal public raw-water sources as brackish but did not foresee any pressing need for brackish-water conversion in the immediate future. State health agency comments indicated that the water sources were only slightly in excess of 1,000 ppm total solids and that adequate water quality was, or could be, provided by present conventional treatment processes.

Seven states—Alaska, Florida, Illinois, Indiana, Louisiana, Texas, and Wyoming—indicated that their brackish-water supplies, 0–7 per cent of all supplies, did not constitute a general problem for the foreseeable future. These states did, however, briefly de-

scribe some local water supply problems of special interest to this discussion. Freeport, Tex., is the site of the US Department of the Interior Office of Saline Water (OSW) gulf coast demonstration plant for sea water conversion. Texas was unique among the states involved in the OSW demonstration plant program in that it had applicants for both the gulf coast sea water conversion plant and the southwest brackish-water conversion plant.

Brackish-water problems of significant interest are, or should be, of major concern in two areas, the northern Great Plains and the Southwest. The states of Minnesota, Iowa, North Dakota, South Dakota, and Montana, and the province of Saskatchewan comprise the northern Great Plains area; Oklahoma, New Mexico, Arizona, and California are the states in the Southwest. Expressed as total number of brackish raw-water supplies, South Dakota, Iowa, Arizona, North Dakota, and California presently have the most serious need for brackish water conversion. Expressed as the percentage of brackish raw-water supplies compared to the total number of public supplies, the order of significance is South Dakota, North Dakota, Saskatchewan, Arizona, and Iowa. Both of these areas are dependent on ground water sources for much of their public supply. The one bright note is that virtually all the larger cities in these areas presently have water of satisfactory chemical quality.

Brackish-water problems have been recognized by those concerned in Iowa, Minnesota, and Oklahoma; however, there have been no significant developments to date. The Montana Board of Health listed an electrodialysis brackish-water treatment plant at Havre Air Force Base as the only recent development in the state. North Dakota had four applicants for consideration as the site of the OSW northern Great Plains electrodialysis demonstration brackish-water treatment plant.

Arizona, with over 28 per cent of its municipal water utilities using brackish sources, is very interested in developments in the field of brackish-water conversion. Safford, Ariz., was one of the applicants for the OSW Southwest demonstration brackish-water treatment plant.

New Mexico had eleven applicants for the OSW Southwest demonstration conversion plant. Roswell, N.M., was chosen as the site for the Southwest plant, which will use the vapor compression process for conversion of brackish well water having 2,400 ppm of salinity.

TABLE 2

Brackish Municipal Water Supplies in Five Provinces of Canada

Province	Total Supplies	Brackish Water Supplies	
		1,000–3,000 ppm total dissolved solids	3,000–10,000 ppm total dissolved solids
British Columbia	281	0	0
Manitoba	41	4	0
Newfoundland	29	0	0
Nova Scotia	44	0	0
Saskatchewan	80	32	1

Saskatchewan municipalities are limited by law as to the amount that may be spent for utility capital improvements. Thus, they have so far been unable to take brackish-water conversion under serious consideration. The Provincial Dept. of Public Health reported that money from provincial funds may be available in the next year or two to purchase an electrodialysis brackish-water conversion plant

for research and development on a municipal water supply.

The California Board of Public Health adopted an "Interim Policy on Mineral Quality of Drinking Water" on Sep. 4, 1959, and has requested its bureau of sanitary engineering to carry out investigations to establish a permanent policy. The interim policy states, "Water supply permits may be issued for drinking and culinary purposes only when the USPHS drinking water standards of 1946 and the State Board of Public Health policy on fluorides are fully met." Temporary permits may be issued at present to water utilities whose raw-water sources do not exceed 1,500 ppm total solids or do not contain more than 600 ppm sulfate, 600 ppm chloride, or 150 ppm magnesium. Coalinga was the first municipality in this country to construct and operate an electrodialysis brackish-water treatment plant, and other California communities may soon follow to comply with the board of public health policy decision.

South Dakota has had a wide variety of experiences with brackish-water conversion, culminating to date in the selection of Webster as the site for the OSW northern Great Plains demonstration treatment plant for brackish water. Twenty cities and towns in the area applied for consideration as the plant site, eleven of them in South Dakota. Three South Dakota communities were among the final six considered by the US Department of the Interior Site Selection Committee, and Webster was finally chosen as the site for a 250,000-gpd electrodialysis demonstration plant. The plant is presently under construction.

South Dakota interest in brackish-water conversion was first stimulated by an OSW electrodialysis test unit operated on a brackish-water well in the city of Miller during the summer of 1955. In the summer of 1959, an electrodialysis water treatment plant was installed on a deep-well brackish source at the Gettysburg Air Force Station. Two South Dakota cities have met with a brackish-water conversion manufacturer, and two additional communities have included brackish-water conversion in a preliminary engineering study of future water utility needs. Electrodialysis water treatment plants are also being specified for deep-well waters at three Titan missile sites now under construction in South Dakota.

State and provincial health agency promotion, consideration, review, and approval of brackish-water conversion proposals for public water supplies will be similar to the present policies regarding conventional water treatment processes. This was evident from the questionnaire replies. Operation and maintenance data from existing brackish-water conversion plants should be carefully evaluated by those responsible, and then widely publicized in the technical literature. The committee recommends that all published operation and maintenance reports include complete raw- and treated-water analyses and a compilation of cost data on a uniform basis like OSW procedure.

The development of the above discussion and compilation was made possible by the excellent cooperation of state and provincial health agencies. Their assistance is gratefully acknowledged.

Distillation of Brackish Water

The use of distillation to purify brackish-water supplies has been largely limited to relatively small units in outlying arid areas of the world. The largest is a 200,000-gpd vapor

compression plant at Dhahran, Saudi Arabia, which has been operating since 1955 on softened well water with about 2,700 ppm total dissolved solids. These vapor compression applications have had the distinction of high fuel economy, with diesel engine drive, up to 300 lb of water per pound of fuel. With most brackish waters, it is possible to maintain this economy by pretreating the feedwater to prevent scale. The resultant conversion cost of $1.50–$2.00 per 1,000 gal has been attractive where other means of supplying water —by transport, for example—would be much more expensive.

There are few, if any, distilling plants operating in the United States that could be called brackish-water plants, although any of the existing vapor compression water units in bottling works or pharmaceutical laboratories would handle brackish water satisfactorily. This situation, however, is changing. Population growth, continued drop in ground water levels, and degradation of existing supplies may make it necessary to consider using water sources that are unacceptable unless the dissolved solids are reduced.

It is generally conceded that $1 per 1,000 gal is an attainable figure with evaporation processes. Considering the concentrations of moderately brackish waters below 5,000 ppm of salinity, it can be said that many of the brackish well and surface waters in the United States can be treated by evaporation at a substantially lower figure than $1 per 1,000 gal in large plants.

Some important factors to be considered when comparing distillation of brackish waters with sea water are:

1. With inland wells, there may be a brine disposal problem, and relatively small brine overflow is desirable.

2. With well, surface, estuary, or river water, the feedwater intake is usually much cheaper and simpler than with sea water. A feedwater intake on the open sea coast can be very expensive.

3. The composition of brackish water varies widely as compared with sea water.

4. The solids content of brackish water is lower than that of sea water. This is not such an important factor with a flash plant, but it results in a substantial decrease in cost of water distilled by vapor compression.

5. Where appreciable solids content in the product is permissible, the dilution of product with feedwater results in a substantial reduction in water cost.

Taking the above factors into consideration, studies show that vapor compression appears to be one of the better evaporation processes feasible at present for inland applications where feed supply is limited.

Some basic limitations in the multiple-effect submerged-tube process strongly suggest that this type will not be competitive for use in treating brackish waters. No comments are made here concerning the long-tube vertical type, as the evaluation of this process will depend on the results of the demonstration plant now being operated at Freeport, Tex.

The cost of treating brackish water would be reduced if dilution were permissible. The distillate from a properly designed evaporator can be regarded as containing substantially no dissolved solids. This purity involves no significant additional capital equipment or operating cost. Where higher solids can be tolerated in the product, there is an important cost reduction by blending the distillate with feedwater, or with water from another source or well. For example, with an

average feed of 2,000 ppm, and with 500 ppm allowable in the final product, a basic cost of $1 per 1,000 gal would be reduced to 75 cents per 1,000 gal. Poorer water supplies might be used and the distillate blended off with fairly good supplies. In this regard, 4,000-ppm feed might be used and the distillate blended with 1,000-ppm water, resulting in a cost of 50 cents per 1,000 gal.

The evaporation process, particularly vapor compression, should find important applications in brackish-water areas in the United States for community use, especially where dilution can be used to the fullest extent. As to cost, it can be expected that further developments will reduce the cost of converting brackish water by evaporation. Perhaps a cost of 70 cents per 1,000 gal might be achieved, which would correspond to 35 cents per 1,000 gal with 1:1 dilution. This would be a noteworthy achievement. Distribution costs and other charges would have to be added if the existing distribution system is not used, but the total cost of perhaps 50 cents per 1,000 gal might be justified for human consumption and some industrial uses.

Membrane Processes

Removal of excess dissolved salts and minerals from saline waters can be accomplished through a number of systems that use selective membranes. When ion-selective membranes are used in conjunction with electric current, the process is called "electrodialysis." Ion-selective membranes can also be used in conjunction with chemical-driving forces like those available from strong brines in the "osmionic" process. Certain other membranes have the property of allowing the passage of liquid under high pressure while delaying the passage of salts and minerals. Such processes are usually called "osmotic" processes.

Of the three types of membrane-dependent processes cited above, only the electrodialysis process has so far emerged from the laboratory and pilot plant stage to become a practical tool in saline water conversion.

As of the end of 1960, commercial electrodialysis equipment having a capacity in excess of 1.2 mgd was already in operation or under construction in over 60 locations throughout the world to supply the fresh-water needs of about 50,000 people and several industrial and military installations.

The electrodialysis process uses d-c electricity to force migration of salts and minerals (in the form of positively and negatively charged ions) through special plastic membranes into a waste brine which is discarded (Fig. 1). The total area of membranes and the quantity of electricity required depend on the total concentration of the salts removed. Accordingly, the cost of this process depends on the level of salinity of the water to be treated. In its present stage of development, electrodialysis appears to be by far the most economical method of removing salts and minerals from so-called brackish waters containing 1,000–5,000 ppm total dissolved solids. The process is also useful for higher concentrations, but above 5,000 ppm, the economic comparison with other processes such as distillation becomes closer.

The prospect for increasing use of electrodialysis in solving saline-water problems is tied closely to the availability of brackish waters in the areas to be served. Fortunately, large areas of arid and semiarid land in the United States and many foreign countries are underlain by brackish ground water resources of significant size. In addi-

tion to the areas of North America, there are many brackish-water supplies among the islands of the Caribbean; in most of the North African, West African, and Middle Eastern areas; in parts of India, Pakistan, and Iran; and in significant parts of South America, Australia, and South Africa.

The conversion of brackish water by electrodialysis should be of immediate interest and usefulness to the water supply field for these reasons:

1. Costs are low enough to be considered for practical full-flow or supplemental municipal supplies in certain situations.
2. Brackish water is available from wells without prohibitive transmission costs to many critically water-short areas.
3. Brackish water from wells generally contains negligible quantities of organic and biological contamination, compared with sea water or surface waters.

Of direct significance for municipal utilities in the United States, three projects are worthy of special mention. The nation's first municipal desalting plant was built in Coalinga, Calif., and has been in continuous and successful operation for more than 2 years. This plant, which supplies fresh water to the second branch of a dual piping system for culinary and drinking purposes, has a capacity of only 28,000 gpd, and its water is distributed among 2,000 water customers, a total of 6,000 people. Its relatively high cost of $1.43 per 1,000 gal has been widely publicized, but it is due primarily to the small size of the installation. It has been estimated that a 2-mgd plant at Coalinga would produce water at 40 cents per 1,000 gal, reducing water of 2,000 ppm to 500 ppm total dissolved solids. The Coalinga unit is extremely profitable for the city, which previously was paying over $7.00 per 1,000 gal for water

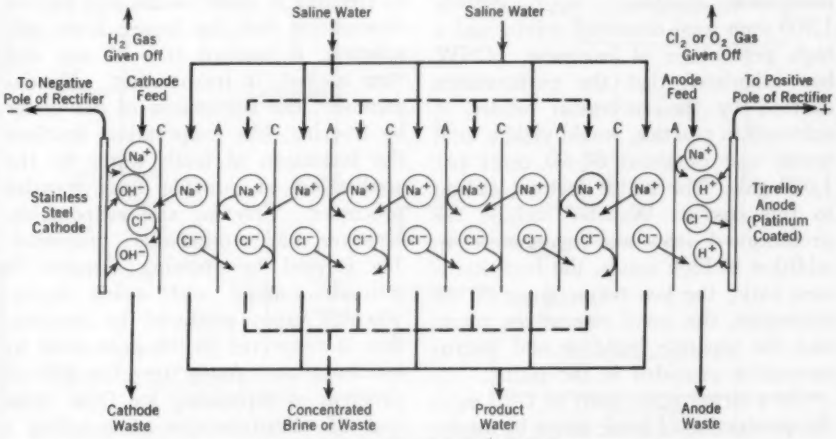

Fig. 1. Ion and Water Flow in Electric Membrane Stack

Membranes marked C are cation membranes; those marked A are anion membranes. The sodium and chlorine ions represented could be any cations and anions.

hauled in by tank car. Its major significance is the proof that a small community without extensive technical facilities or technically trained personnel can successfully operate electrodialysis units, and that the water produced is an acceptable product for critical culinary and drinking purposes.

During 1960, OSW let a contract for a 250,000-gpd electrodialysis unit at Webster, S.D., as a part of its demonstration program. The water to be treated contains 2.4 ppm of iron and manganese combined, approximately 1,800 ppm total dissolved solids, and a high percentage of hardness. OSW has calculated that the performance claimed by the successful bidder, if achieved in practice, would yield a total water cost of about 80–90 cents per 1,000 gal. The major factors leading to this cost at Webster include the presence of iron and manganese in addition to high solids, the high hardness ratio, the low temperature of the feedwater, the small size of the plant, and the separate building and instrumentation provided in the plant.

On a larger scale, such as 1–10 mgd, the production of fresh water by applying electrodialysis to brackish waters in the 1,000–5,000-ppm range should cost 30–60 cents per 1,000 gal under reasonably favorable conditions, and possibly less, as this process is undergoing rapid technological improvement. Only slightly higher costs should prevail for plants of as little as a few hundred thousand gallons capacity.

The state of the art of saline-water conversion by electrodialysis may be likened to the electric-power industry, which has seen its residential costs drop from 6.5 cents to 2.5 cents per kilowatt-hour in the past 30 years as power generation equipment has become more efficient. Going back further to Edison's day, it took 10 lb of coal to generate 1 kwhr of electricity; now it takes less than 1 lb. The water demineralization business may, so to speak, be back in Edison's day. A long road of technological improvements and subsequent cost reductions lies ahead; there is much hope for more economical water from brackish sources.

Freezing Processes

The demineralization of saline water by freezing is based on the well known observation that ice frozen from salt solution, if washed free of salt and then melted, is fresh water. Fundamentally, the conversion of sea water by freezing, like evaporation, involves the formation of fresh water by the application of suitable heat transfer processes. Freezing and evaporation, however, are otherwise dissimilar. Ice formed by freezing remains in intimate contact with saline liquor, whereas vapor produced by evaporation is recovered in the pure state by condensation. Aside from the difficult problem of separating ice from brine and the disadvantages of handling a solid phase, the freezing method offers advantages worthy of consideration. First, freezing has the natural advantage of an inherently low energy requirement; second, it may be accomplished at or near atmospheric pressure, and at low temperatures which minimize scaling and corrosion; and finally, the process is basically simple, requiring for the most part low-cost construction materials and equipment of modest size, indicating a potentially low-cost operation.

One of the major problems associated with the development of the freezing method is the separation of ice from the brine. Because the brine is strongly held within the interstices of

the ice crystals, considerable washing is required to effect separation. Recently the problem has been resolved in part by the development of more efficient wash-separation techniques. Among the more promising approaches in this connection are counter-current washing, involving hydraulic piston action and flooded percolation of the ice bed, and the technique of controlled crystallization in which the size of ice crystals is increased to facilitate removal of salt. These methods, together with multistage washing in which saline liquor is first displaced by solutions of progressively lower salt concentrations and finally by pure water, are currently being investigated.

There are at present two leading techniques for economically producing sea water ice: freeze evaporation and direct refrigerant cooling (Fig. 2 and 3). The first freezing saline-water conversion pilot plant of any appreciable size was constructed as a 15,000-gpd pilot plant at Harbor Island, Wrightsville Beach, N.C. This is currently under test to prove the method on actual sea water.

In this method, sea water is introduced into a high-vacuum chamber and flash cooled to a temperature low enough to produce ice crystals. The water vapor is an additional source of desalinized water and is either mechanically compressed for condensation or handled by an absorption unit.

In the other leading freezing process, a refrigerant such as isobutane is introduced directly into the brine, thus freezing some of the solution into ice crystals. The use of a direct refrigerant greatly reduces the size of compressor needed as compared to the

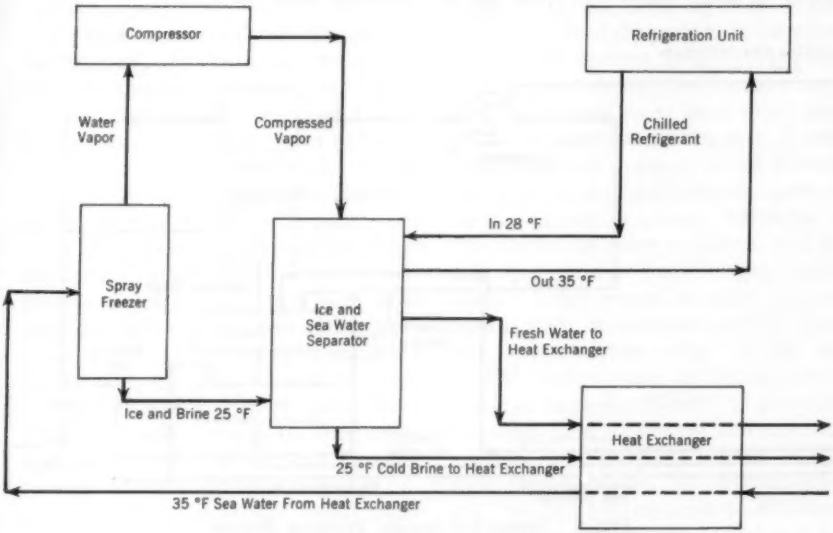

Fig. 2. Freeze-Evaporation Process

Flow diagram shows that both ice crystals and water vapor produced in spray freezer are sources of desalinized water.

other cycle, but adds the complication of handling a second fluid with little or no loss allowed. A pilot plant of 35,000 gpd was recently completed near St. Petersburg, Fla., for direct testing of sea water.

Although the development of freezing processes is not far enough along to make firm cost estimates, it appears that either of these two methods shows promise for producing demineralized water at $0.50–$1.00 per 1,000 gal in plants of very large size and for sea water. Brackish-water demineralization should be slightly less expensive, as ice separation requirements are lower.

A demonstration plant to be located at Wrightsville Beach, N.C., which uses one or another of the above variations, will be a true pilot plant designed to advance a freezing process to its commercial prototype phase. Design will start this spring.

Solar Distillation

Solar distillation is basically simple in principle. Historically, it is an old art. A frequently mentioned application is the 50,000 sq ft solar still built in Chile in the 1870's to supply water for a mining camp. Like many other conversion methods, however, basic improvements and fundamental analysis of the process with the reduction of operation costs in view have only recently been considered.

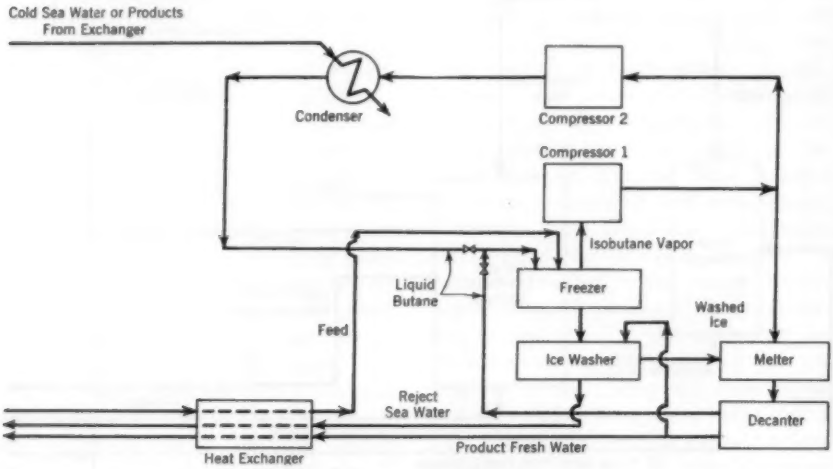

Fig. 3. Direct-Refrigerant Freezing Process

Refrigerant, such as isobutane, is introduced directly into the brine, freezing some of the solution into crystals.

Some of the advantages of the process are: (1) the need for an outside energy source is eliminated, thus making the process attractive in areas where fuels are unavailable or expensive; (2) materials used for construction are ordinary building supplies rather than elaborate mechanical or process apparatus; and (3) units are of comparatively simple design, involving no moving parts. Scale-up from small to large units is readily made

because it normally involves only multiples of a basic unit; (4) construction can be made by comparatively unskilled labor as compared to some of the more complicated conversion equipment; (5) solar stills require a minimum of water pretreatment. The product is of high quality, and (6) scale formation is not a problem in solar stills, as the water absorbs the heat directly from the solar radiation without the usual transfer through a metal barrier.

Factors unfavorable to the process include: (1) the diffuse nature of solar energy imposes stringent limitations on the capital costs that can be expended in collecting the solar radiation falling on a given area, (2) capital charges are increased by the unavailability of solar radiation at night, (3) large land areas are required to obtain reasonable quantities of water, (4) greater damage may result from wind and hail storms than with other processes, and (5) solar energy availability limits its application to certain areas.

Applications for solar stills have greatest promise in areas of high average solar intensity where other energy sources are unavailable and fuel is expensive. Both large and small units are adaptable to these areas. The small units, however, also have favorable possibilities for use in the lower-cost fuel areas, where they may have advantages in certain applications. The process is well adapted to individual, household, and small commercial plants. Because of area requirements, multimillion-gallon-per-day plants do not appear probable, but plants of 100,000 gpd appear to be reasonable.

Production units are at present limited in number and restricted to those of very small capacity. Several small production units are in operation in Australia and North Africa. Technology has advanced so that such production units can be effectively constructed today, but the cost of the units is still a limiting factor. Present operating conditions are such that with solar radiation of 2,000–2,600 Btu/sq ft/day water production of 0.1–0.15 gpd/sq ft is to be expected. This yield represents about 50 per cent efficiency in the conversion of solar radiation to heat for water distillation. As a convenient rule-of-thumb figure, 0.1 gpd/sq ft, or about 5,000 gal/acre/day may be used as a measure of the yield to be expected.

Primary interest today is therefore in the research and development work directed toward more economical solar stills. Reductions in the cost of solar distillation are being achieved through two approaches, designing the units so as to achieve maximum efficiency in the use of the solar radiation, and obtaining the lowest possible construction costs. Improvement in stills involves both a study of materials and the physical design of the units. In the still design studies many individual developments have contributed to progress. Detailed heat balances and thermal analysis have provided a basis for design improvements. The deep-basin still has been introduced to eliminate the need for the ground insulation required in shallow-basin stills; tilted and envelope designs have been introduced to take advantage of the larger percentage of incident solar radiation intercepted and to eliminate insulation requirements. Forced circulation as opposed to natural circulation has been proposed and tested, and it has been found that a larger percentage of the solar radiation can be utilized through this technique. Designs with plastic construction, using low air pressure to inflate the stills and eliminate other structural supports, have been built and are now being tested. Multiple-

effect solar stills have been built and operated on a laboratory scale for the purpose of reusing the solar heat in successive stages. To date, however, this system has not shown cost advantages over the simple still. Early in this laboratory work, economic analysis was made of the operation of conventional multiple-effect evaporation units using steam generated with solar energy collected by mirrors or reflectors. Costs were too high to be competitive with other methods. More recently, a similar analysis of a still using a solar-heated pond indicates greater promise than the previous approach. Some consideration has been given to the storage of solar energy for possible night use of solar stills. In the materials field, plastic films for canopy construction, asphalt and plastic films for economical ground construction in the basin stills, and coatings for plastic films to produce wettability and ultraviolet reflectiveness have been investigated.

Briefly, the results of these studies have indicated that both glass and plastic films have merits in solar still construction. The results with plastic films have been very promising, but the full potential of these films is yet to be determined. In the physical design of the units, present technology and economic analysis have indicated that the simple solar still has greater potential for ultimately reducing the cost of solar distillation than other arrangements. A simple solar still may be defined as one combining the solar heat absorber, evaporator, and condenser as a single-effect integral unit like the greenhouse or tilted and envelope type of still. This concept differs from the multiple-effect solar still, the forced-circulation still with external condenser, and the system using mirrors or reflectors for conventional-type distillation units. As already noted, however, designs other than the simple still, such as the solar pond and the forced-circulation concepts, have demonstrated promising potential, and future technology may well reveal merits for other designs.

Estimated costs of solar distillation have been discussed in the various OSW technical reports and in other publications. Water produced by the small present-day units would undoubtedly cost several dollars per 1,000 gal. Cost predictions [1] are difficult because no large units have been built.

Other Developments

Aside from the above processes, for which pilot plants have been built and operated on natural saline waters, a number of other methods are in various stages of laboratory research and development. Additional work is needed on most of these methods to make an appraisal of their effectiveness in reducing the cost of saline water conversion. Of recent interest is the so-called hydrate process based on the formation of solid hydrates with various substances, particularly the hydrocarbons and their derivatives. This is a chemical process related to freezing in many respects. Further investigations of the hydrate method are needed to determine fully what its potential may be. The solvent extraction and osmionic processes are in the advanced phases of laboratory research. These two methods are limited primarily to the treatment of brackish waters. With the osmionic method, which obtains its energy for salt removal entirely from a more concentrated brine, conditions must be favorable for providing a concentrated brine source. Other methods currently under study include electrolytic regeneration of ion-

exchange resins, electrically induced adsorption on porous graphite electrodes, utilizing the mineral residues in waste brines, developing membranes for reverse osmosis, study of the behavior of metals in sea water at high temperatures, and various methods for preventing scale formation in conversion units. Calcium sulfate scale has been of particular interest because of the difficulties normally encountered in its prevention. In the distillation processes, stabilization techniques using recirculation of sludge and softening by ion exchange using the waste brine as regenerant are under investigation for calcium sulfate scale prevention. In electrodialysis, studies are being made of calcium sulfate scale prevention using stabilizing additives like sodium hexametaphosphate to permit operation with supersaturated solutions.

Economics and Logistics of Competing Supplies

Increasing emphasis must be given to the economic evaluation of saline-water conversion with respect to its competing water supply processes. This evaluation is commonly made for all other engineering projects. The major competitor is conventional water supply, typically the impoundment of surface water or the tapping of ground water and the transportation of the raw water from the source to the point of treatment, and then distribution to the users. Saline-water conversion, typically from a local ground water source, would eliminate the impoundment, the transmission, and possibly some of the treatment. Total costs of water should be estimated on a standardized basis like that proposed by OSW [2] so that all economic factors will be taken into consideration. The cost of saline-water conversion in comparison with conventional supply is indicated by the relation between saline-water conversion costs to the costs of impoundment, transmission, and treatment of conventional supply, and these costs only.

Stated briefly, the costs of impoundment and transmission for large capabilities are so low that they constitute difficult competition for saline-water conversion when fresh-water sources are readily available and the capacity to be stored and transmitted is large. When small municipalities and industrial consumers have exhausted their supplies within reasonable distances, saline-water conversion of local ground water may become economical for them.

In some communities having brackish water, improvement of the existing public supplies by demineralization may require a substantial rise in water rates. Present water costs, however, may not be as cheap as the consumer is led to believe. For example, in a typical town using highly mineralized water where the average monthly water bill may be $4–$5, one or more of the following additional "water-connected" expenses might be commonplace: (1) purchase of bottled drinking water—$3–$6 per month, (2) home softening—$3–$10 per month, (3) excess corrosion due to the highly mineralized nature of the water—$4–$6 per month; (4) excess consumption of soaps and detergents (in cases where no softener is used)—$4–$5 per month. It is clear that substantial increases in water rates of such communities would lead to delivered water prices above present national averages, or even above some current high-price areas. There is no natural law or principle, however, that all water rates must be in the neighborhood of 20–60 cents per 1,000 gal. Substantial variations in utility costs

are commonplace in different locations with different natural endowments.

The premium that communities are willing to pay for stored water will gradually diminish as familiarity with demineralized brackish water becomes more general. Communities that today have highly mineralized water will learn within a few years that the quality of their water can be improved markedly at an economical cost. Demineralized brackish water will become increasingly important as a water resource in some areas of our nation.

One good installation of significant size, producing a good-quality water from a highly mineralized source at a cost equal to or less than the delivery of stored surface water, will make a lasting impression on the community in which the installation is located. Later on, other communities will learn of the success and reliability of the demineralization process. Obviously, although cost is a most important factor, of equal importance is the reliability of the demineralization process. It must work satisfactorily and continuously, and should not require highly trained operators. When this stage has been achieved, demineralized water will take its place as an important source of fresh water.

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Discussion

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By presenting developments in saline-water conversion, this report renders a genuine service to municipal and industrial water supplies. It was wise to confine the first report to brackish waters, as they are the major problem at present, and will be such for many years.

It is particularly helpful to have a clear definition of the term "brackish water." If this definition is accepted in use, it may help people to avoid some of the present confusion on this matter.

The writer agrees with the task group recommendation that all published operation and maintenance reports on brackish-water conversion plants should include complete analyses of raw and treated water along with a compilation of cost data—and that these analyses and data should be presented in a form like that of OSW. The writer's firm has completed a new membrane electrodialysis unit, manufactured under license rights from a Netherlands research group. This plant will be installed at Pickstown, S.D., to produce fresh water from brackish water for an Air Force installation. The firm plans to publish complete reports, including cost information, on this plant.

The task group report describes two processes that are commercially available for treating brackish water: distillation and electrodialysis. The freezing process, now being tested by OSW on a pilot plant scale for sea water, will probably not be considered for commercial installations until it has been successfully used, and until costs have been established in a demonstration plant. The OSW demonstration plant program does not include a

freezing plant for brackish-water conversion.

The writer's experience in recommending, designing, and building equipment for brackish-water conversion has shown that there are many variables between one application and another. The section of the task group report that deals with membrane processes confirms this finding, and mentions that the OSW demonstration plant at Webster, S.D., the site of which was selected because of its "typical" water conditions, may not be representative of other "typical" plants. Variables other than water composition to be considered in selecting a process are: (1) cost of electric power at the plant site, (2) cost of available fuels, (3) availability of waste heat sources, as from a steam power plant, and (4) Total solids concentration requirements in the final product. As pointed out in the distillation section of the report, dilution of product water can reduce water costs by 25–50 per cent.

The writer has found, in studying the requirements for a municipality where a good water supply had to be provided from brackish water in the 1,000–3,000-ppm range, that it was impossible to predict the optimum process without a complete cost study of the electrodialysis process, the distillation process, and combinations of these processes. It is interesting to note that for this particular installation, the cost of energy plus amortization costs varied more than 100 per cent between the several schemes considered.

For an installation with a capacity as large as 24,000 gpd, the vapor compression type of plant frequently has a lower capital equipment cost and a lower total operating cost than the corresponding costs for an electrodialysis plant. For example, with a plant of 2,000-gpd capacity, which would produce water of 500 ppm total solids from water of 3,500 ppm total solids, the equipment selling price of the writer's firm for electrodialysis (including pretreatment) is approximately $20,000. A vapor compression plant including pretreatment equipment, on the other hand, would cost approximately $10,000. The electrodialysis plant would use 3.7 kw/hr; the plant of the vapor compression type would use 5.7 kw/hr. On smaller plants, the increase in electric-power requirements of the vapor compression plant is offset by other cost factors such as capital equipment, water pretreatment, membrane replacement, and operating labor. Other applications, however, favor the electrodialysis process.

In the section of the report on membrane processes, present costs for electrodialysis are stated to be in the range of 30–60 cents per 1,000 gal. A 2,800-000-gpd plant in South-West Africa, also built under license rights from the Netherlands group, has reported costs of 54 cents per 1,000 gal, but the writer knows of no installations in the United States that produce water in the 30–60-cent range. The writer believes the 54-cent costs in South-West Africa can be reduced in a United States installation with presently available equipment.

The writer questions the implications that electrodialysis is the most useful method for the water supply profession. Both distillation and electrodialysis, or a combination of those processes, must be considered for each brackish-water application. Only after a careful, impartial analysis can it be determined which process or combination of processes will result in the lowest total water cost.

Water Supply on the Moon

Harry N. Lowe Jr.

A paper presented on Jun. 7, 1961, at the Annual Conference, Detroit, Mich., by Harry N. Lowe Jr., Deputy Chief, Missile & Space Office, US Army Engr. Research & Development Labs., Fort Belvoir, Va.

THE current pace of technical advances in space vehicle propulsion and guidance suggests that the capability to transport men and materials to the moon will be achieved by the end of the 1960's. To permit early exploitation of this capability, life support systems must be devised that will permit men to live and work for extended periods on the moon.

Food, water, and oxygen, essential to survival in any environment, will make up a large portion of the logistic support load for any manned lunar operation. A normal active man consumes 1,800–2,000 lb of water in 12 months. The total requirement for water for all purposes may be as high as 15,000 lb per man a year. To reduce the logistic burden to manageable proportions, it is essential that sustained manned operations on the moon be supported by systems of recycling and reuse of water that greatly reduce or eliminate need for resupply of water from Earth.

The objectives of this article are to outline the problem and to identify some of the areas in which research effort is indicated.

Environmental Factors

The moon is a rocky sphere, 2,160 mi in diameter. Its surface environment is much more hostile than any yet encountered by man. Selected astrophysical data are shown in Table 1. It is apparent that man's survival on the moon for any extended period will require construction of protective shelter and other facilities.

The prime requisite in design of a lunar base will be to provide an environment in which man can live and do useful work, and which is, as far as practical, similar to Earth conditions. Some basic environmental requirements for man are shown in Table 2. Maintaining this required environment on the moon will require creation and control of a breathable atmosphere in pressurized shelters and within protective clothing. This will involve means of replacing oxygen; removal of carbon dioxide and other contaminants; control of dust, odors, and sound; and maintaining desired levels of humidity, pressure, and temperature.

It has been postulated that water may exist as ice at the bottom of deep craters or beneath the surface of the moon. This theory is based on the assumption that water was once present on the lunar surface. Lunar rocks have been suggested as a water source for permanent bases in which heavy machinery and large power sources could be installed. This approach assumes that lunar materials contain significant trapped and bound water. Evaluation of these and other possible sources will require far more knowledge of the physical structure and environment of the moon than is cur-

rently available. At present, it must be assumed that the moon is devoid of water. In the absence of lunar water sources, we must look to three other sources for water: (1) the Earth, (2) man's excretions, and (3) other wastes.

All water requirements on the moon could be met by shipment of water in sealed containers from Earth. Initial supplies will be provided in this manner. It is estimated that it will cost $1,000–$5,000 per pound to transport cargo to the moon. Cost alone suggests that some other method of supplying at least part of the required water will be desirable. Technical considerations indicate that a major reduction in the total weight of water transported from Earth will be essential in any extended lunar operation.

Production of potable water on Earth for use on the moon will pose no significant problems. Development of suitable containers will be required. Protection of stored water against enviromental hazards must be provided.

The second available source is man's excretions, which can be processed to allow at least partial recovery of the water content. The amounts of water available from human excretions are indicated in Table 3, which shows average water excretion based on a total excretion of 2,500 g per man per day. These figures show that the principal sources of excreted water are (1) urine and (2) the atmosphere containing water from the lungs and skin. The amount of water contained in feces is relatively small.

It is difficult to estimate at this time the amount of water to be expected from other wastes. In temporary facilities, there may be essentially no water used except that consumed directly by man. In more formal facilities, the utility water requirements may exceed 4 gpcd. Wastes will include water from bathing, cleaning, and food preparation. These wastes will probably contain chemical disinfectants and other substances, and may be more representative of industrial wastes than of domestic sewage. If hydrogen-oxygen fuel cells are used for power generation, the resulting by-product will be water that may contain significant quantities of dissolved metals.

Man as a source of water should not be overlooked. Although the amount produced varies between individuals and with diet, the human body is a producer of water as a by-product of the metabolic processes. Water output may exceed input by 12–20 per cent.

TABLE 1

Selected Astrophysical Factors for the Moon

Factor & Unit	Value
Specific gravity	3.33
Acceleration of gravity at surface—*ft/sec/sec*	5.31
Ratio of moon gravity to earth gravity	0.162
Albedo*	0.07
Temperature, surface, daylight—°*F*	214
Temperature, surface, night, minimum—°*F*	−270
Temperature, subsurface, constant, at equator—°*F*	−40
Atmosphere, surface pressure—*earth atmospheres*	10^{-12}

* The ratio of light reflected from the moon to the total light falling on it.

Operational Factors

Lunar water systems will vary with the type and mission of the facilities they serve. Extraterrestrial bases may be classified as follows:

1. *Temporary base.* A base intended for use for a limited period of

time and providing only minimum facilities to sustain life and to support the mission of the assigned personnel. A landed, manned space craft with an externally constructed power source represents the simplest temporary base.

2. *Semipermanent base.* A base designed for a useful life of 1 year or more of continuous or intermittent occupancy without major maintenance and providing an intermediate comfort level for personnel. A semipermanent base may provide a closed ecologic system but requires major logistical support.

TABLE 2

Environmental Requirements for Man

Requirement & Unit	Limit	Remarks
Oxygen—%	20.7	optimum; may be increased at reduced pressures
Nitrogen—%	78	optimum
Inert gases—%	1	
Carbon dioxide—%	0.3–0.5	maximum for continuous exposure
Pressure—*psi*	14.7	may be as low as 10 psi in lunar suit
Humidity—%	50–60	
Temperature—°*F*	65–68	optimum
Noise—*decibels*	30–40	maximum for comfort
Water—*lb/day*	6	internal use; may be lower for short periods

3. *Permanent base.* A base designed for an indefinite period of continuous occupancy, providing a maximum practical comfort level for personnel, and requiring little, if any, logistic support from Earth. A permanent base provides a closed ecologic system and is supported by an industrial system that utilizes available natural resources to produce most essential supplies, which may include food.

Water supply systems for temporary bases must be light in weight, and must require minimum maintenance and power. The use of other than stored supplies of water must be carefully evaluated against the weight, power required, and other characteristics of water recycling systems. Water recycling systems will be a firm requirement in all semipermanent and permanent facilities. In facilities designed for extended use, power will not be a limiting factor and the designer of water supply systems will be guided by the requirements for reliability, low maintenance, and long life.

Suggested Research

Review of the literature suggests that many investigators have recognized the importance and complexity of water supply problems on the moon, but that only limited research has been accomplished. Significantly, more attention has been given to water supply systems for use on space vehicles intended for relatively short periods of use and in a zero gravity environment. Some of the work reported was accomplished with only limited attention to the unique logistical requirements of extraterrestrial operation. Reliability and long-term costs are more significant than noncritical differences in technical performance or apparent large differences in first cost. Lack of attention to the environmental factors on the moon, including gravity, temperature, and pressure, could produce processes of little practical value. The required research, development, and evaluation testing of systems must be conducted under controlled simulated-environment conditions, where possi-

ble. Results must be evaluated in pilot plant operations and through effective and timely use of test animals and humans. This is a time-consuming but essential procedure.

Water Recovery From the Atmosphere

Removal of moisture from the atmosphere is a firm requirement in every manned space vehicle, full pressure suit, and inhabited lunar structure. The task can be accomplished by any one of several methods. A mechanical method employing refrigeration appears promising for lunar applications that involve extended periods of operation. It is considered likely that a multistage mechanical refrigeration system can be used to remove both water and toxic gases from air. Required research includes study of methods for removing water from air by compression, by adsorption, and by cooling, using as aids the environmental conditions found on and below the surface of the moon. Required water treatment research includes studies of removing particulates, dissolved gases, and other objectionable contaminants from the water obtained from the atmosphere. Methods to reactivate materials used to remove tastes, odors, and toxic materials must be studied as well as effective disinfection and protection of the finished product.

Water Recovery From Liquid Wastes

Most investigators agree that urine can be used as a raw-water source with relatively high efficiency of recovery of water. No significant attention has been given to recovery of water from other liquid wastes that may differ significantly from urine in physical and chemical characteristics. It appears desirable, therefore, to study these two wastes separately and together. Research should include investigations of the requirements for, and the performance of, processes involving filtration, ion exchange, electrodialysis, and the phase change processes of distillation, freezing, and sublimation. Of these processes, distillation appears to offer the most promise for simple systems requiring only limited logistical support, although the effects of high temperatures on volatiles normally carried over in the distillation process deserve careful attention. The lunar environment with its subfreezing and boiling temperatures, low pressure, reduced gravity, and high levels of solar radiation should be considered in the design of the experiments. These factors may be troublesome, but they may also provide essential aids to new approaches to the problems.

TABLE 3

Water Available From Human Excretions

Source	Amount of Water g/day
Lungs	500
Skin	500
Urine	1,400
Feces	100

Water Recovery From Feces

Human feces are the least promising source of water in a waste recycling system, largely because of the relatively small amount of water available. Required research in this area includes studies of dewatering feces alone and when combined with urine, urine brine, other liquid wastes, and garbage. The nature of the dewatered residues should be determined to permit evaluation of them as food for algae and in other applications.

Discussion and Summary

Significant lunar environmental factors have been noted. Potentially productive areas of research have been suggested that should be explored and exploited in developing water supply support for manned operations on the moon. A system based on recycled wastes, supplemented by resupply of water from Earth, is not the only possible solution to initial water supply problems on the moon. No other approach offers a better solution, however, within the time frame of the anticipated need.

There has been only limited research accomplished on lunar water supply problems. For the next few years, the required effort will be an extension of existing data and experience associated with water purification, waste treatment, industrial hygiene, and preventive medicine. The current state of the art will not support equipment development. The initial effort must be concerned with processes, techniques, and the unexplored hazards to man resulting from continuous use of a recycled water supply. Providing safe and reliable water supplies on the moon will not be an easy task. With an effectively organized and vigorous research effort, it is safe to assume that the problems will be solved early enough to meet the requirements for design and construction of lunar facilities. A research program to produce firm guidance to system designers within 4 years appears to be a reasonable objective.

Many of the technical problems of water recovery from wastes on the moon are known to those now engaged in research on sea water conversion and water purification from the increasingly contaminated sources on Earth. It appears reasonable to assume that this effort to meet the water supply problems of those who will go to the moon will also produce new data and concepts of substantial value to those who remain at home.

Revised Gate Valve Standard Available (AWWA C500)

Copies of AWWA C500–61—Gate Valves for Ordinary Water Works Service, containing the revisions approved by the Board of Directors on Jan. 23, 1961, are now available from the AWWA Order Department at 25 cents each.

The principal revisions to the document, formerly designated AWWA C500–59T, affect Sec. 6, 10, 12, 28, and 29. With the inclusion of a new Sec. 31 (Affidavit of Compliance), the former Sec. 31 (Preparation for Shipment) becomes Sec. 32. The document has been advanced to Standard status.

Water Consumption by Institutions

Phillip E. Searcy and Thomas deS. Furman

A paper presented on Nov. 14, 1960, at the Florida Section Meeting, Ft. Lauderdale, Fla., by Phillip E. Searcy, Sr. Asst. San. Engr., USPHS, Charlottesville, Va., and Thomas deS. Furman, Assoc. Prof. of Civ. Eng., Univ. of Florida, Gainesville, Fla.

CONTINUED increase in population is forcing communities to expand into outlying fringe areas. Schools, churches, stores, shopping centers, restaurants, and motels follow this expansion and are established on the suburban fringes. These areas are often beyond the reach of existing public water and sewer systems. When it is not economically feasible to connect the new areas to the existing systems, it becomes necessary to build adequate facilities to serve the institutions in their new locations.

Proper design and operation of such facilities require prior knowledge of the quantity of water to be used and of the hydraulic flow characteristics expected. The accuracy of these design data is of utmost importance. If flows are underestimated, the plant capacity will be insufficient and the operating efficiency greatly reduced. If flows are overestimated, the plant will be larger than necessary, thus making the cost of the plant excessive.

In view of the expected continuation of present community expansion trends, and of the pressing need for factual design data for treatment facilities to serve institutions, a study of water consumption rates affecting small treatment plant design was initiated at the University of Florida in the spring of 1960. The purpose of the study was to obtain and evaluate basic water consumption data, to compare them with existing information, and to establish, if possible, reliable water

TABLE 1

School Water Consumption Based on Monthly Meter Readings

Type of School	Consumption—*gpd/student*		
	Average	Maximum	Minimum
Average elementary	5.8	12.9	0.2
Typical* elementary	8.3	11.1	3.5
Average junior high	6.0	16.2	0.1
Typical* junior high	7.0	16.2	0.1
Average senior high	11.7	36.8	0.4
Typical* senior high	15.8	36.8	1.2
Combined	12.0	18.6	1.9

* One school selected as typical of modern design and construction.

TABLE 2

School Water Consumption Based on Daily Meter Readings

Type of School	Consumption—*gpd/student*		
	Average	Maximum	Minimum
Average elementary	7.5	10.6	5.5
Typical* elementary	8.2	10.6	6.6
Average junior high	6.5	12.2	4.1
Typical* junior high	7.1	7.8	6.3
Average senior high	19.9	61.3	9.1
Combined	13.5	14.9	12.3

* One school selected as typical of modern design and construction.

consumption rates which could be used in the design of small water and sewage facilities.

Objectives

To establish these data, the following objectives were set:

1. Determine the average, maximum, and minimum consumption rates on a monthly, daily, and hourly basis.
2. Determine the relationship between average, maximum, and minimum consumption rates.
3. Present reasonable flow factors which may be used in the design of treatment plants to serve the institutions studied.
4. Present any other relationships that might affect the design of treatment plants for the institution studied.

If a study could adequately meet these objectives, the authors believed it would be possible to select design flows that would accurately reflect the actual flows to be expected from a specific type of institution.

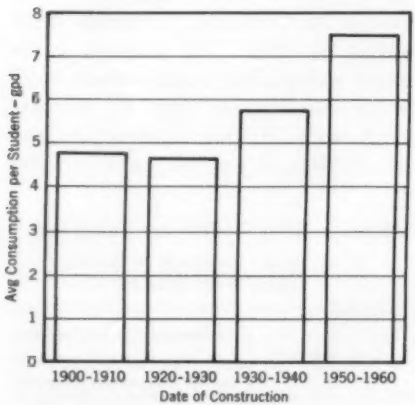

Fig. 1. Water Consumption and Age of Schools

Consumption is based on monthly averages over an 18-month period.

TABLE 3

Motel Water Consumption

Period	Consumption—*gpd/guest*		
	Average	Maximum	Minimum
Monthly readings	63	181	24
Daily readings	54	111	21
Hourly readings	57	320*	

* Peak hourly flow.

A review of existing data on water consumption rates disclosed little information of this scope. Most of the previous studies presented average values only, and were based on monthly consumption records with no consideration given to daily or hourly variations.

The first extensive compilation of institutional flows was apparently made by John E. Kiker Jr.[1] Several other compilations have followed, but for the most part, they seem to be only an expansion of the original compendium. One of the most recent surveys appears in the USPHS *Manual of Septic Tank Practice*.[2]

According to the records of John E. Kiker Jr., a recent approach to the problem of determining water consumption rates in schools was made by a Florida governor's committee on school sanitation. This committee, appointed by Governor Collins in 1958, made preliminary investigations of available data and established a tentative schedule for an exhaustive study of consumption rates in Florida schools. Unfortunately, the study has not been completed.

A study of monthly water consumption rates for shopping centers in the

Miami, Fla., area was made by Loyd Frank Vann Associates in 1959.

As stated above, the purpose of this study was to examine not only the monthly records, but the daily and hourly water consumption rates as well, and to make these findings available as a basis for future design.

Procedure

The first step in the study was the selection of the institutions to be studied. After careful consideration, it was decided to limit the study to schools, motels, shopping centers, hospitals, and restaurants in the Gainesville, Fla., area. The data were taken from monthly records accumulated by the city and from hourly and daily meter readings obtained specifically for the study. At frequent intervals during the survey, all data were reviewed to insure proper coverage of the various types of institutions.

The season of the year was also a considered factor in the study. Field readings were made in February and March. According to interviews with school principals and motel managers, this season had certain advantages and one disadvantage. The advantages of this time of year were:

1. Showers in schools were heavily used because sports activities were at their peak.

TABLE 4

Restaurant Water Consumption

Period	Consumption—*gpd/meal*		
	Average	Maximum	Minimum
Monthly readings	7.7	17.3	2.4
Daily readings	6.4	12.6	3.2
Hourly readings	7.3	16.5*	

* Peak hourly flow.

TABLE 5

Shopping Center Water Consumption

Period	Consumption—*gpd/1,000 sq ft*		
	Average	Maximum	Minimum
Monthly readings	209	278	130
Daily readings	175	217	82
Hourly readings	217	451*	

* Peak hourly flow.

2. The tourist season was at its peak; the motels and restaurants were serving a maximum number of guests.

3. Very little water was being used for lawn watering and other outside uses. Hence the water being consumed would closely approximate actual sewage flow.

The primary disadvantage was that cold weather generally reduces the amount of water used per capita. This reduction could reduce the possibility of obtaining maximum consumption rates, but it was concluded that the advantages outweighed the disadvantages, and that February and March represented an ideal time for the study.

Consumption rates for each type of institution were obtained on a monthly, daily, and hourly basis. The monthly rates were obtained from the city records; an 18-month period from Oct. 1, 1958, to Apr. 1, 1960, was selected for analysis.

Daily readings were taken directly from the water meters of the institutions selected. Readings were begun on Feb. 9, 1960. At least fourteen readings were made at each location.

Hourly studies were made on selected days throughout the 2-month period to obtain maximum consumption rates from which the relationship between average and peak consump-

tion rates could be computed. In order to obtain a better indication of peak rates, some readings were taken at 30-min intervals during periods of maximum consumption.

All consumption rates, whether obtained from monthly, daily, hourly or 30-in. readings, were converted to gallons per day, thereby establishing a common factor for each type of institution and aiding data comparison.

From each group of institution the one unit considered the most typical or representative of present-day design and construction practice was selected. The rates for this typical unit were compared to the average values obtained for the group. Such a comparison was made to establish typical individual data as well as average group data, and thereby produce realistic results.

Schools

Schools were given top priority in this study because little consumption data on schools is available and because many schools are being constructed in areas not served by public water and sewerage facilities.

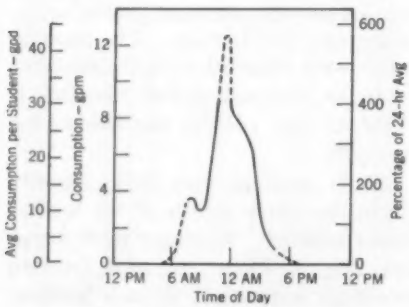

Fig. 2. Water Consumption of an Elementary School

During the 10-hr period covered by the study, 93 per cent of the total daily flow was consumed.

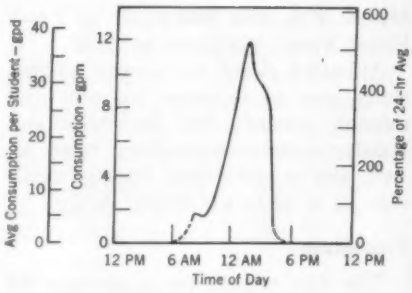

Fig. 3. Water Consumption of a Junior High School

The 4-hr maximum consumption rate was higher than that of the senior high school.

In the Gainesville, Fla., city school system there are ten white and four Negro schools which can be divided into nine elementary schools, two junior high schools, two senior high schools, and one combined school (kindergarten through twelfth grade).

All elementary schools were equipped with cafeterias. The junior and senior high schools and the combined school included a cafeteria and a gymnasium with showers.

Soon after the beginning of this study it was found that consumption in schools varied with the type of school (elementary, junior high, senior high, or combined) rather than with the facilities of the school (cafeteria, gymnasium, showers). Of the schools studied, the junior high, senior high, and combined schools each have a cafeteria and a gymnasium with showers, yet the consumption rates of each were significantly different.

Consumption rates were reported in gallons per day per student, as this unit of measurement has been used in all previous tabulations. It was observed in this study, however, that there is not always a direct relationship between water consumption rates and the number of students in attendance. Variations in water consumption appeared to be more nearly related to special activities of the school. These include lawn watering, sports events, construction work, and other water-consuming activities. Nevertheless, the number of students does indicate the size of the school, and was therefore used as the denominator for consumption rates.

The average daily attendance records were obtained from the Alachua County Board of Public Instruction, and were used in determining consumption rates on monthly and daily bases. On days selected for hourly studies, an actual census was taken to determine the attendance on those particular days. Monthly consumption rates were based on an average of 22 school days per month for regular school months and 15 school days for December.

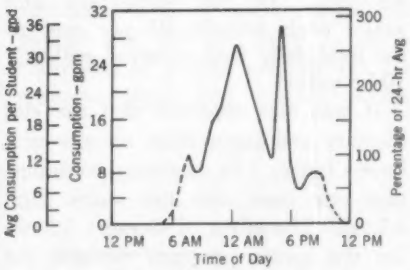

Fig. 4. Water Consumption of a Senior High School

The second peak in the consumption rate reflects showers that students take after the daily sports activity.

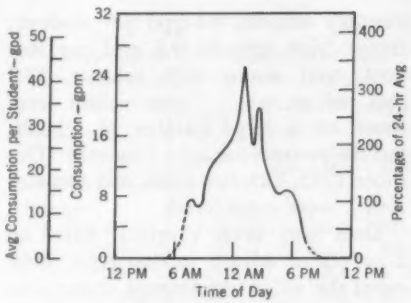

Fig. 5. Water Consumption of a Combined School

The combined school, like the senior high school, has two peak consumption rates.

The situation during the summer months was found to be unique. Except for a small summer school enrollment over a 6-week period, there was no student attendance; yet in some cases an appreciable amount of water was consumed. This can be explained by the fact that most major repairs and new construction are made during the summer months, and much of this work requires large volumes of water. In order to convert this water consumption to gallons per day per student, the average daily attendance for the month of May was used for June, July, and August, and the actual number of days in each month was used rather than the number of school days. The average monthly consumption records for the 18-month period are presented in Table 1.

Data reported by the governor's committee on school sanitation gave the following average consumption values for Dade County, Fla.: ele-

mentary schools, 9.4 gpd per student; junior high schools, 9.3 gpd per student; and senior high schools, 12.4 gpd per student. These values were based on a large number of schools, but the records for only 3 months (October 1955, October 1956, and October 1957) were considered.

Data from West Virginia,[3] based on a survey of schools in that state, indicated the following average water consumption values: elementary schools, 5.1 gpd per student; high schools, 8.7 gpd per student; and combined schools, 6.2 gpd per student. As a result of this survey, West Virginia has adopted the values of 10 gpd per student for schools without showers and 20 gpd per student for schools with showers.

Daily consumption records were collected at various times throughout the study and the results are presented in Table 2.

It may be noted that the average consumption rates are lower than the rates for the representative school. As the representative schools are of more recent construction, they are better

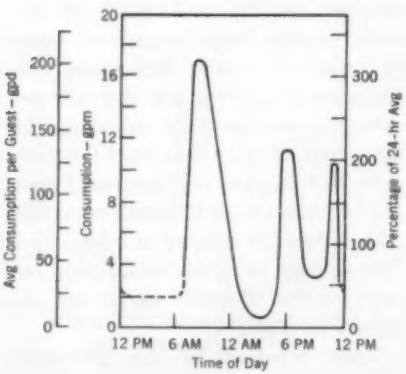

Fig. 6. Water Consumption of a Motel

Flow rates for motels do not include water used in motel restaurants.

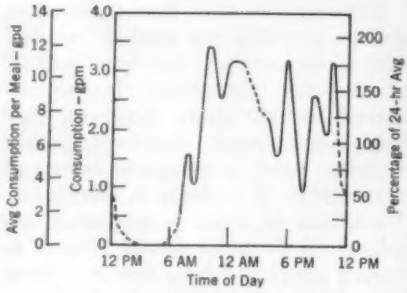

Fig. 7. Water Consumption of a Restaurant

The restaurants taken for this study served three meals a day.

equipped than the older schools. This led to a comparison of water rates with the age of the school. The results are indicated in Fig. 1.

At least 2 days were devoted to obtaining hourly meter readings at each of the school types studied. The only exception was the combined school, where only one set of readings was obtained. These results are presented in Fig. 2–5.

It was noted that over 82 per cent of the water used each day was consumed in the 10–14 hr covered by these readings. In the elementary and junior high schools, 93 per cent of the total daily flow occurred within a 10-hr period.

It was also observed that the elementary and junior high schools each have a higher 4-hr maximum consumption rate than does the senior high school. The effect of showers following the sports program explains the second peak in the consumption rates of the high schools and the combined schools.

A review of all data collected in this phase of the study led to the selection of certain factors that relate aver-

age daily values to certain maximum consumption rates. These factors are based on an analysis of monthly, daily, and hourly consumption rates, and although they may not hold true for all conditions, they should give a close approximation of flow relationships that can be expected in the various types of schools. For elementary and junior high schools they are: 12-hr maximum, 2 times the 24-hr average; 4-hr maximum, 4 times the 24-hr average; 1-hr maximum, 5 times the 24-hr average. For senior high and combined schools, they are: 12-hr maximum, 1.75 times the 24-hr average; 4-hr maximum, 2.5 times the 24-hr average; 1-hr maximum, 3.25 times the 24-hr average.

Motels

Six motels were selected for study. Two had restaurants which were served by separate meters. Another had a coffee shop which served breakfast only, and three had no restaurant facilities.

Water consumption rates were reported as gallons per day per guest and do not include water used in restaurants. For design purposes, the gallons per day per guest could be translated as gallons per day per bed space—a single bed counted as one bed space and a double bed counted as two bed spaces. The consumption records are presented in Table 3.

Investigations of a motel selected as representative of present-day design indicated the following consumption rates: 24-hr average, 65 gpd per guest; maximum 12-hr average, 93 gpd per guest; maximum 4-hr average, 166 gpd per guest; peak hour, 292 gpd per guest. The pattern of the hourly flow rate for the typical motel is shown in Fig. 6.

It was found that the average consumption rates based on monthly records exceeded those based on daily and hourly readings. This is probably due to below-average consumption for the 2 months considered. Although business was at its peak, water consumption was not. Very little outside water use, such as lawn watering, was observed during the months considered, and this probably accounts for the difference.

TABLE 6

Hospital Water Consumption

Time Interval	Consumption—*gpd/bed*		
	Average*	Maximum	Minimum
Monthly readings	241	277	185
Daily readings	247	307	193
Hourly readings	305	578†	

* The number of beds for which the hospital was designed was used as denominator.
† Peak hourly flow.

TABLE 7

Summary of Water Consumption Data

Institution	Suggested 24-hr Avg Flow *gpd**	Flow Factors†		
		12-hr Max.	4-hr Max.	1-hr Max.
Schools				
Elementary	10	2.0	4.0	5.0
Junior High	12	2.0	4.0	5.0
Senior High	20	1.75	2.5	3.25
Combined	14	1.75	2.5	3.25
Motels	70	1.5	2.5	4.5
Restaurants	9	1.4	1.7	2.0
Shopping Centers‡	250	1.5	1.9	2.1
Hospitals§	275	1.25	1.75	1.9

* Denominator for schools is student; for motels, guest; for restaurants, meal; for shopping centers, 1,000 sq ft; for hospitals, bed.
† Factors by which 24-hr average flows are multiplied to obtain various maximum values.
‡ Based on a shopping center with floor area of 133,458 sq ft.
§ Based on a 120-bed hospital.

From the data collected the following flow relationships are suggested: 24-hr average, 70 gpd per guest; 12-hr maximum, 1.5 times 24-hr average; 4-hr maximum, 2.5 times 24-hr average; 1-hr maximum, 4.5 times 24-hr average.

Restaurants

Two restaurants and one cafeteria were included in the study. The restaurants were operated in conjunction with two of the motels and the cafeteria was a part of the shopping center. Three meals per day were served by the restaurants, and two were served by the cafeteria. Consumption rates, based on the average number of meals served per day, are presented in Table 4. The flow pattern of hourly consumption rates for a typical restaurant is shown in Fig. 7.

Shopping Centers

Only one shopping center was available for study. It contained 21 shops and one apartment and covered 133,458 sq ft of floor space. As each shop had a separate water meter, it was necessary to read 22 meters and combine the results in order to secure the desired information. The results computed in gallons per day per 1,000 sq ft of floor space are as presented in Table 5. A typical flow pattern of hourly consumption rates is shown in Fig. 8. It was observed that 77 per cent of the 24-hr flow was consumed in a 12-hr period.

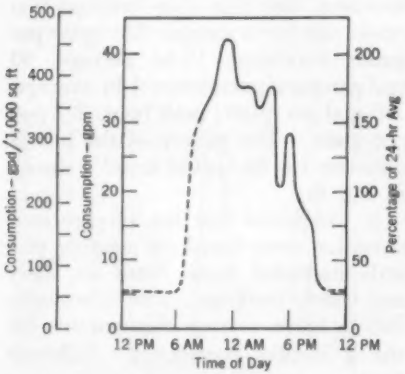

Fig. 8. Water Consumption of a Shopping Center

Readings from the 22 meters serving the shopping center were combined to determine total consumption.

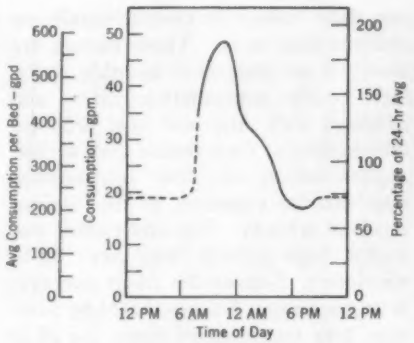

Fig. 9. Water Consumption of a Hospital

The hospital used for this study was designed for 120 beds, although the number of patients often exceeded the design bed space.

As previously mentioned, the firm Loyd Frank Vann Associates of Miami made a study of water consumed by shopping centers in that area. This study revealed that the amount of water consumed per 1,000 sq ft increases as the size of the shopping center increases, and that a shopping center containing less than 100,000 sq ft used an average of 161 gpd per 1,000 sq ft, whereas a unit containing over 300,000 sq ft used an average of 225 gpd per 1,000 sq ft, based on monthly records.

Based on this information and on the present study, considering monthly, daily, and hourly variations, the average daily consumption for shopping centers of the size studied was computed at 250 gpd per 1,000 sq ft. The following flow relationships were computed; 12-hr maximum, 1.5 times 24-hr average; 4-hr maximum, 1.9 times 24-hr average; 1-hr maximum, 2.1 times 24-hr average.

Hospitals

Only one hospital, the Alachua General Hospital, was available for study. This hospital was originally designed as a 120-bed institution, but has had to provide temporary bed space to handle the increasing patient load.

As initially computed, consumption rates were based on the number of patients, but it soon became obvious that little correlation existed between the number of patients and water consumption. Therefore, the water consumption was recomputed and based on the design bed space (120 beds). The results are presented in Table 6. A typical hourly flow pattern is shown in Fig. 9.

Summary

The results of the study are summarized in Table 7, which shows suggested flows for the institutions studied, and flow factors that may be used to convert average readings to desired design criteria. Although it must be understood that the values presented are based on a limited number of samples, it is felt that the results are reasonably reliable for typical institutions. Allowances, however, should be made for special problems or conditions that might affect water consumption rates in other locations.

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Bill Collection Procedures and Delinquent Accounts

Joint Discussion

A joint discussion presented on Apr. 14, 1961, at the California Section Meeting, Santa Barbara, Calif.

Procedures at Vallejo—*Robert B. Hunter*

A paper presented by Robert B. Hunter, City Water Supt., Vallejo, Calif.

THE Vallejo (Calif.) Municipal Water System would not be considered a big business when compared to some of the larger utility companies in California, but it would certainly not be called a little business either. Its service area extends beyond the municipal boundaries and includes not only Greater Vallejo but also several other communities extending over most of the southwestern half of Solano County. The system is in the 20,000-customer class and distributes about 4.5 bil gal of water a year. Its annual income is approximately $1,500,000.

Income is, of course, as essential to a water utility as it is to any other business. The utility must be certain of receiving a steady flow of income over given periods if it is to meet its operational costs, provide the degree of service the public demands, and continue its replacement and capital improvement programs. Billing and collection bring in the utility's income.

When collecting payments of water bills, the privately owned water company may have a slight advantage over the publicly owned company. A substantial number of customers feel that the service from a publicly owned utility need be paid for only when they, the customers, can do so without inconvenience, but that the water, being publicly owned, must nevertheless continue to be delivered without interruption. Contrary to this opinion, it is only fair that all customers pay for water as received, and that billing and collection provide equal distribution of the payment burden. Customers who pay their bills regularly should not be penalized in the rate structure or otherwise be required to take up the slack for those who do not pay bills when due. Assuming that a proper and adequate rate schedule has been established, the next step is to initiate sound billing and collection procedures.

A little more than 3 years ago, Vallejo adopted a new ordinance establishing rules and regulations for the municipal water system. This ordinance, in part, outlines procedures to be followed, commencing with the application for service, procedures during the service period, and payment of the final bill.

Service Application

The ordinance states that the applicant for water service or his authorized representative must appear in the commercial office and complete a service agreement that defines:

1. The premises to be served (address or location)
2. The owner of the premises, if other than applicant
3. The nature of the water use (residential, commercial, or other)
4. The estimated water demand (in gallons)
5. The date the commencement of service is desired
6. The bill mailing address.

Service Agreement

When completed and signed by the applicant, the application form becomes the service agreement. The form is a 4×6-in. card that, because of its simplicity, requires very little clerical time to complete. It has eliminated or reduced some of the collection problems by positively identifying the customer and clearly defining the service period. The act of signing this agreement also has a psychological effect on the customer, causing him to recognize more clearly his responsibility for paying bills. The size of the card makes it easy to file while the account is current. If the account becomes delinquent to the point where shutoff is required, or if the account is not paid on termination of service, the service agreement with the amount of the delinquency noted thereon is transferred to the blacklist file.

When he signs the water service application, the applicant agrees to:

1. Pay for all water delivered through the service connection from the date of the commencement of service to and including 2 working days after the delivery to the commercial office of a written request for discontinuance of service
2. Pay all bills for the service within 30 days after the date of billing.

Service Deposit

The service application indicates whether the prospective customer is the owner or the tenant of the premises for which he desires water service. If the applicant is the owner of the premises, no deposit is required. Nor is a deposit required of a tenant who has previously had a water service account with Vallejo without being delinquent for twelve consecutive billings. Deposits are required of all tenants whose credit has not thus been established. The size of the service deposit is the average 2-month bill for the particular classification of water consumption, but, in any event, the deposit is not less than $10. Deposits are refundable on termination of service at the particular location and on payment of the closing bill, or after twelve consecutive billing periods in which the account has not been delinquent at any time.

Billing

For billing purposes, accounts are divided into two general categories, monthly and bimonthly. Monthly bills are issued for:

1. All contractual accounts, which consist primarily of government agencies
2. Customers consuming more than 20,000 cu ft of water in any 2 consecutive months
3. Customers remote from the Greater Vallejo service area.

Bimonthly bills are issued to the remainder of the accounts, which include the majority of the residential consumers and those business or commercial activities using relatively small quantities of water. The bimonthly billing procedure was adopted to minimize rising operational costs and overhead and thereby retain an economic balance without increasing water rates.

It should be noted here that although bimonthly billing reduces meter-reading and billing costs, it frequently increases or compounds collection problems. The 2-month bill will naturally be larger than the bill for 1 month and, therefore, be more difficult for some customers to pay. With 2-month billing, a leak in the customer's facilities can, and generally does, continue undiscovered for a greater period of time. And those customers, of whom all utilities have a few, who do not intend to pay the bill will have an additional 30-day start out of town. Vallejo's billing schedule is organized so as to process customer accounts at a uniform rate each working day during the billing cycles.

Delinquency Reminder

When water bills are made out, the billing information is entered on the ledger for each customer. As payments are received, they are posted on the ledger, and the outstanding balance, if any, is then readily available.

When, in the course of issuing bills, an account is found to have an outstanding balance, a delinquency reminder is sent to the customer, indicating the need for prompt payment. The reminder briefly advises the customer that the records indicate his account to be delinquent, repeats the 30-day payment provision of the ordinance and the customer's service agreement, and states that it is to the customer's best interest to have a financially healthy utility. The reminder also explains that the utility's financial health is necessary to continue service at the required level and to carry out planned improvement programs, and that to remain financially healthy, the utility must keep its accounts and collections correct and thus have a balanced income.

Shutoff Notices

If a 30-day review of the account discloses a continued delinquency, a shutoff notice is delivered to the customer, indicating the amount of payment required and the deadline date before which the payment must be received. The deadline date is normally 5 working days after the date of notice. This final notice also states the penalties in the event the service is disconnected for nonpayment of the bill.

Whenever a water service has been shut off for nonpayment, it cannot be restored until all charges due, including a $3 turn-on fee, have been paid and a cash deposit made to reestablish the customer's credit. If, after a service is discontinued for delinquency in payment, service is resumed without proper authorization, the meter is removed and a $5 replacement charge is made, in addition to the charges and deposit mentioned before, before service will be reinstated.

Vallejo has the usual run of hard-luck cases: customers who for some reason find themselves in financial difficulty and those who receive bills for excessive quantities of water resulting from a leak or other loss. Cases involving customers who are unable to pay within the prescribed time are handled individually and without the inconvenience of service discontinuance,

if the customer can conclusively demonstrate that the delinquency will be remedied within a few days.

Bill Adjustments

When the reason for an unusually large bill is positively traced to a leak or other loss of water, the bill is adjusted. Adjustments of this type can be made only after repairs have been completed and when it is reasonably certain that the leak or loss will not be repeated. It is further provided that no more than one bill adjustment or allowance for a leak or loss shall be made to the same customer or for the same premises within any 12-month period.

Adjustments of this type are readily justified, as the customer did not use or otherwise receive any benefit from the water. The adjustment is determined by deducting the quantity of water represented by the customer's average bill, with the remaining water being the excess amount subject to adjustment. The excess quantity is billed at the lowest rate provided in the rate schedule, resulting in the leaked or lost water being paid for as though it were sold to a large consumer. If, by then making the lowest rate applicable, the utility recovers all of its production costs, nothing has been lost, and some collection problems may have been eliminated with the reduction of an otherwise excessive bill.

Whenever the meter readers encounter a service for which the meter has recorded a substantial increase over its normal rate of consumption, a notice is left with the customer. This notice calls the increase to the customer's attention and advises him that if he cannot account for that volume of use to contact the commercial office.

Whenever a customer complains or inquires about a high meter reading or billing, a field inspection is made of the premises to determine if a leak or loss has occurred. The inspectors are trained to use this opportunity to explain the workings of the water meter and the procedures of reading and billing. This type of program is useful in eliminating the usual customer complaints about overreading, reporting readings without visiting the meter, and confusing one meter reading with that of another account.

Past Experience

It has been Vallejo's experience that, although delinquencies cannot be completely eliminated, they can be held to a minimum by:

1. Taking every opportunity to educate the consumer public about the water company's activities, methods, and policies
2. Adopting a billing and collection procedure that is realistic, and firmly enforcing the procedures with courtesy and tact, treating all customers fairly.

It is clearly evident that lax procedures or weak enforcement of billing and collection will decrease or delay earned income. Delinquencies breed delinquencies—that is, to allow delinquencies to go unchallenged is to have them pyramid rapidly throughout the service area. A utility cannot engage in idle threats. There are some people who will take the easy way out—they will defer and frequently attempt to avoid their obligation if the utility fails to carry out its announced collection regulations. Regardless of regulations, ordinances, or policies, the job of billing and collection requires public education and personnel who are alert, diligent, and persevering in their efforts and who do not overlook any

opportunity to follow up and attempt to collect delinquent accounts.

Vallejo's records indicate that approximately 20 per cent of the customers relocate within the service area of the municipal water system each year, and that about 2 per cent move to locations served by other companies.

Experience has shown that, although approximately 8 per cent of the system's dollar billing is delinquent during any billing period, less than 0.2 per cent of the total billing is uncollected after 12 months. This is not intended to mean that uncollectible accounts, regardless of how small the percentage, are acceptable. The utility does not write off these accounts as loss but continues, in every way possible, to try to collect them.

Procedures at EBMUD—*Kenneth D. McCloskey*

A paper presented by Kenneth D. McCloskey, Mgr., Commercial Div., East Bay Munic. Utility Dist., Oakland, Calif.

The collection procedures and policies used by any utility are the result of a series of compromises designed to safeguard the utility against loss of revenue and still maintain good customer relations. These compromises attempt to encourage and eventually force a customer to pay and, at the same time, keep him reasonably happy with the utility. They attempt to apply to both the conscientious customer who occasionally forgets to pay and the chronic delinquent who tries to outsmart the utility. They attempt to meet the credit needs of the utility and yet not differ too radically from what may be accepted as standard credit practice in the community. Thus, collection procedures are more apt to be the result of human judgment than the result of scientific formula. The practices of the East Bay Municipal Utility District (EBMUD) are no exception to this.

Organization

To describe clearly the collection procedures of EBMUD one should first describe the organizational relationship of the units that are involved in these procedures. The accounting division reads the meters, prepares and mails the bills, sends out notices of delinquency, and maintains all records of customer payments and customer deposits. The commercial division receives customer payments, takes necessary action to enforce customer payments, determines credit requirements, and handles any customer complaint regarding the accuracy of the bill. The accounting functions are performed in a central location; the commercial functions are performed in six decentralized business offices located conveniently in the service area of the district.

Methods of Payment

Customers of EBMUD have a number of choices as to how and where they may pay their bills. The business offices collect approximately 12 per cent of the revenue. Drive-in windows have been provided for the convenience of customers in the district's three newest business offices, and a fourth office is scheduled for installation within the next 6 months. Slightly less than half the collections of these offices are made at drive-in windows. Business office field per-

sonnel collect an additional 1 per cent of revenue from their work on delinquent accounts.

Most of the bills are paid by mail. During the 6-month period October 1960–March 1961, mailed bills amounted to 74 per cent of all bills paid. Banks and other agencies accounted for the remaining 13 per cent of the revenue. Five of the district's agencies have self-service depositories. All payments are picked up each day, and the account records give an up-to-date status of customer payments.

Collection Procedure

The customer receives his bill 5 working days after his meter is read. He automatically receives a reminder notice 25 days later if his bill has not been paid, and 17 days later he receives a two-item bill and a final notice advising him to pay on a certain date to avoid an interruption in service. By this time, 47 working days have elapsed since his meter was first read. Two days later, the accounting division checks the two-item notices for payment and sends the unpaid bills to the appropriate business offices for collection action. The unpaid bills amount to approximately 3 per cent of all the bills.

At this point, the commercial division comes into the picture. An attempt is made to communicate with the delinquent customer by telephone; this is accomplished in about one-third of the cases. When the customer can be reached, every effort is made to commit the customer to pay his bill within a very few days. This has proved to be quite effective and efficient, especially when employees are properly trained and have a good telephone personality.

All delinquent accounts that have not been reached by phone are turned over to field forces the following day for collection action. Field forces are also given those accounts that failed to comply with their telephone commitments. It is necessary and desirable to give field personnel a certain amount of latitude in granting modest extensions of time when this is the reasonable thing to do. It is obvious, however, that such extensions cost money in manpower and increased risks, and there is a limit to how much one can spend to effect collections. The district tries to limit extensions to approximately 3 days.

If no reasonable and satisfactory arrangement for payment can be made with the customer, his meter will be locked. This unpleasant experience happened once for every 280 bills submitted in 1960, a percentage of 0.3. If water is turned off for failure to pay a bill, a penalty charge of $2 is made for turning on the service.

Closing Bills

The procedure for collecting closing bills is similar to that for collecting routine bills, but is a longer process. The customer does not receive his bill quite as soon after the meter is read because of the special handling required. Approximately a month after the customer receives his closing bill, action to collect the bill is begun. Normally this begins with a low-pressure reminder letter. If the bill is more than $1 and the customer's new residence is in the district's service area, a followup is made in 2 weeks with a call on the customer. This process is repeated 2 weeks later with a stronger letter, and another attempt is made to collect the bill. A final

letter informing the customer that his bill will be turned over to a collection agency is mailed 2 weeks later.

On the third Thursday of each month, the accounting division takes from the suspense file all closing bills 4 months old or more and sends them to the business office for review. The business office indicates those few accounts that should not be turned over to the collection agency. The balance of the accounts are turned over to the agency at this time, after approximately 5 months of collection action have passed.

Collection Agencies

EBMUD has had very good luck with collection agencies. Currently, the collections from agencies are approximately $8,000 per year, or close to one-third of the amount of the bills assigned to them. The use of a collection agency probably is helpful too because of the psychological value it has when referred to in conversations with delinquent customers. The average person will think twice before he permits himself to get into the clutches of a collection agency. Many customers pay the district directly, even after they have been called in by the agency.

EBMUD has been very careful in selecting collection agencies. It uses two agencies that do collection work for the other utilites in the area. This gives the district a great advantage, as the agencies can afford to spend a considerable amount of followup time on one of the district's delinquent customers if he also has delinquent telephone and electric bills. The agencies have been satisfactory also because they use relatively low-pressure collection methods that are effective in most instances without causing too much customer resentment. The agreement with the agencies precludes them from suing a delinquent customer without the district's permission.

Deposits

The district's policy is to require a deposit from each residential customer who does not satisfy at least one of these conditions:

1. The customer has had prior district service for a period of at least 1 year and has a satisfactory payment record.
2. The customer is currently employed by an established firm or company or a governmental agency and has been with this company for a minimum of 1 year.
3. The customer has been self-employed, a building trades worker, or engaged in some other independent activity for a minimum of 1 year and has a record of stable employment.

The employment must be local, unless the customer's past work history indicates exceptional stability of employment. The job itself should be the type that is likely to result in stable employment.

Deposits are collected from a new commercial or industrial customer unless one or more of the following conditions are satisfied:

1. The customer is part of a firm that has established a satisfactory district credit rating and is doing business in the same name.
2. The customer is part of a large national or statewide firm.
3. The service is taken out in the name of a customer who has established a satisfactory district credit rating for a comparable service.

The minimum deposit required is $15. This is the deposit for a residential customer and would apply to many of the smaller commercial firms.

Deposits are established to equal approximately 2.5 times the estimated average bill. This represents the average length of time a customer may use water without its being shut off because of nonpayment of bills.

A deposit is refundable after 1 year, provided the customer has a satisfactory payment record. The refund may be made at the business office, or the customer may request a refund by mail. If the customer has not requested a refund within 1 year from the date he becomes eligible for it, the district mails a refund check to him. Obviously, the customer also becomes eligible for a refund on termination of service, if he has paid his bills. No interest is paid on customer deposits.

A customer may be required to reestablish his credit because of repeated delinquency in the payment of his bills. In such instances, he must put up a guarantee deposit in the same amount as any new customer who cannot meet the credit requirements of the district.

The district has gone through several cycles in its policy on deposit requirements. At the present time, the requirements are about as rigorous as they have ever been. This has had the desirable effect of bringing the district's writeoff down to a very low figure. During the last fiscal year, the writeoff was 0.11 per cent of revenue. This means that the district collected $99.89 of every $100 billed. The writeoff per account during the same period was 6.6 cents.

Future Plans

Pleased as the district is about its collections, it feels that it must critically appraise its policies and procedures from time to time. It must determine whether collections have resulted in the best possible balance between the needs of the district and the needs of its customers. At the present time, the district is critically examining its deposit requirements, collection followup, and employee selection and training.

Even though EBMUD has few really serious complaints about its deposit policy, it realizes that the policy adversely affects customer relations. In an attempt to modify this policy, the district has developed a system for the coding of all residential accounts. With this system, a customer's code would indicate the number of times he had been delinquent during the previous 12 months. A zero would be perfect; a six would mean that the customer had been delinquent on every bill. The new customer would be given a special code. Collection action would be varied depending on the customer's delinquency pattern. If he was rarely delinquent, the district would not worry too much about him and would spend little time trying to collect his bill. On the other hand, both a customer who was often delinquent and a new customer would be subjected to much more drastic collection action. The district believes that it could make its efforts at collection much more effective if it had this kind of system, and conceivably could even have a better collection record with less effort and expense than with its present system. Of almost equal importance is the fact that the district might be able to discontinue the collection of deposits from most of the new customers who do not now meet the credit requirement.

Deposit requirements on commercial and industrial accounts would be continued on approximately the same basis as at present. The major difference would be that the deposit would be retained for a longer period of time. Some of the biggest commercial risks,

such as restaurants and launderettes, probably should have a deposit retention schedule of approximately 5 years.

EBMUD is planning to revise its collection letters and forms. These have not been changed for several years, and the district believes that it can modernize the letters and forms and improve their effectiveness. This could be most helpful in reducing man-days spent on some of the more routine collections.

One of the greatest areas of possible improvement lies in the field of better employee selection and training. The district has found, for example, that certain employees have an amazing knack of talking a delinquent customer into paying his bill. On the other hand, some employees seem not only to be exceptionally unpersuasive but also to antagonize the customer. The district is trying to refine and raise the minimum qualifiations for hiring and to use oral boards for screening prospective employees. Undoubtedly, much could be done to train employees to make them more effective with customers.

Procedures at California Water Service Company

Ralph D. Lindberg

A paper presented by Ralph D. Lindberg, Vice-Pres. & Treas., California Water Service Co., San Jose, Calif.

Every business extending credit has the problems of collecting bills and dealing with delinquent accounts. As it is not practical to provide water service on a pay-as-you-go cash basis, a water utility is in the credit business and must face the problems incident to that mode of business. Although a water utility may discontinue service for nonpayment of bills, this procedure is neither desirable nor inexpensive, so that the basic objective for a water utility is the same as that for any other business: to make collection at the least cost and maintain the goodwill of the customer.

Billing

The California Water Service Co. owns and operates seventeen water systems designated as districts. The customers' bills are prepared in a central billing plant, but all other customer accounting is decentralized or performed in the district offices. A postcard type of bill for monthly service is sent by first-class mail to each customer.

The company follows the practice of establishing agencies in drug stores, variety stores, gift shops, and other stores for the customer's convenience in paying bills. The agencies have authority only to collect current bills; they do not have authority to accept applications for service or receive complaints. For the company as a whole, approximately 15 per cent of all bills are paid through store agencies, but the percentage varies considerably among localities. In some districts, collections by agencies exceed 25 per cent of the total. The percentage of bills paid by mail also varies in different communities, from approximately 50 per cent to 75 per cent of the total bills paid.

Reminder Notice

The bill mailed to the customer contains a statement or notification that the bill is due and payable upon pres-

entation and will become delinquent if not paid within 15 days after presentation. But if payment is not received within the 15 days, no reminder action is taken during the first month. If full payment is not received prior to the next billing date, the delinquent balance is entered as a separate item on the next month's bill, and a reminder sticker may be attached to the bill. As postal regulations prohibit dunning requests on bills mailed as postcards, no matter how politely worded, the bill with the reminder notice must be mailed in an envelope requiring 1-cent additional postage.*

Sampling tests in selected districts have indicated that the effectiveness of reminder notices requiring additional expense is questionable. In order to appraise further this phase of the collection procedure, selected districts are at the present time mailing 2-month bills (current month plus delinquent balance) without reminder notices; other selected districts are affixing the stamp impression "due from prior period" opposite the delinquent balance. A favorable ruling has been obtained from the post office that these words may be used without inserting the bill in an envelope.

Final Notice

If no response is received from the customer, the 2-month bill is followed by a final or shutoff notice. The normal procedure is to mail the final notice 10–20 days after the mailing of the bill carrying the delinquent balance. The number of final notices prepared and the time passed since the mailing of the last bill must be correlated with the collection force available for timely followup on accounts that are not paid within the period allowed. On the average, more than 75 per cent of the accounts receiving final notices will respond with payment. In some areas, however, home calls by collectors will be required for 50 per cent of the notices; in other areas, for only 10 per cent of the notices. Adjustments in the scheduling of collection work are made from time to time in accordance with the experience of individual districts.

The time limit entered on the final notice must be at least 6 days from the date of mailing and must not fall on a Saturday, Sunday, or holiday. The collector has authority to grant extensions of time if there is sickness in the family or if payment is promised within 2 days. Local management is given complete discretion with respect to the latter circumstance in order to deal effectively with chronic delinquents. Also, at the discretion of local management, shutoffs for nonpayment are not made after certain hours in the afternoon, in the interest of minimizing the number of turn-ons after working hours.

The employees assigned as collectors for the company do not wear a uniform but carry identification cards. They are instructed to be neat in appearance and courteous in manner. In most areas, they are expected to average about four calls per hour.

Deposits

The rules and regulations filed with the public utilities commission permit the company to collect a meter deposit from applicants establishing credit who do not meet any one of three conditions—the applicant:

* A phrase like "Reminder Notice—Please Pay Promptly" may, however, be used on a postcard bill. It is best to get a specific ruling from the local post office on what is acceptable.—EDITOR.

1. Is the owner of the premises or other real estate in the area
2. Furnishes a satisfactory guarantor
3. Has been a customer within the past 2 years and has not had his service shut off for nonpayment during the last 12 months of service.

The rules also permit the collection of a deposit, before restoring service, from customers whose service was discontinued for nonpayment. The deposit must be refunded, together with interest, after the customer has paid his bills within 15 days after presentation for 12 consecutive months.

As a general rule, the company has found that the bookkeeping required to maintain the "prompt payment record" is not commensurate with the value of the deposit. Often a good customer will pay his bill each month but will fail to meet the 15-day requirement because the company's cycle billing does not correspond to his pay day or check-writing day. Also, full followup on the collection is usually required, because the amount of the deposit is less than the total amount of the bill. The company has, therefore, made local management responsible for the evaluation of credit risks and has permitted management to use discretion in either requiring a deposit or waiving it in instances when a deposit is permitted under the rules filed with the public utilities commission.

Closing Bills

The company's followup procedure on closing bills, when the customer has moved from the service area, consists of four attempts by mail to effect collection before the account is turned over to a collection agency. The mailings consist of: closing bill, reminder closing bill notice, first collection letter, and second collection letter. The mailings are made at 15-day intervals, with each action entered on an index card placed in a 15-day file. Each day, the cards due for action that day are checked. If the bill is still unpaid, the communication next in order is mailed, posted on the card, and the card placed 15 days ahead in the file. If two successive communications are returned by the post office, the routine is no longer followed, and the account is given to a collection agency.

Bad-Debt Loss

Each office maintains a bad-debt card file of accounts uncollected during the 4 preceding calendar years. The file is kept at the counter and referred to each time a prospective customer applies for service. In evaluating the effectiveness of a collection system, consideration should be given the current status of the accounts, the percentage of bad-debt loss, the amount of collection expense in relation to prompt payment and bad-debt loss, and, very important, proper relations with the customer.

Approximately 20 per cent of California Water Service Co. accounts are billed as 2-month accounts; 1.5 per cent as 3-month accounts. A bad-debt loss of less than 0.2 per cent of revenues is maintained. The maintenance of this favorable bad-debt loss, however, has required collection expenses equal to twice the amount of the bad-debt losses. The company has found that any curtailment in collection activities almost immediately results in increased delinquent accounts. Ideally, there should be a proper balance between the amount of delinquent accounts, bad-debt loss, and related expenses. If this goal is to be reached, collection procedures must be constantly reviewed and changed.

Legal Action—*Emanuel Becker*

A paper presented by Emanuel Becker, Deputy City Attorney, Los Angeles, Calif.

Although water is an essential commodity, its general availability is such that almost everyone who is not connected with an organization serving water to the public takes water service for granted. Almost every customer who receives water service pays his bill. Only a small number who demand the service do not pay their bills, making legal action necessary.

Importance of Applications

Before legal action to effect collection of delinquent bills is discussed, consideration should be given to preventive action with regard to bill collection. The steps taken when a person applies for water service should be examined thoroughly.

An application complete with information establishing the applicant's identity, credit status, location to be served, and signature helps minimize the need for future legal action. In this regard, an appropriate slogan is "an application well taken is an account half collected."

An application for service has to be taken if only to learn the location to be served. The cost of obtaining a complete application is always a factor for consideration. The cost of the additional time of the service representative, whether he deals with the applicant in person, by mail, or by telephone, has to be considered and compared with the efforts that might be needed at a later date to learn the whereabouts of the customer who has not paid his bill.

If an application is taken, it should be processed first to enable the utility to commence service as soon as possible. Thereafter, it should go immediately to the credit unit for review. The credit manager and his staff can quickly reexamine the application and determine the need for more information. Perhaps a deposit is needed because the applicant is a poor credit risk or is in a risk business, such as a restaurant, which can be opened and closed between billing periods.

When the credit unit has finished its work, the application should be filed. If the applicant was a former customer who did not pay his bills, such information should be in the application file. At this time, the file clerk should check to see if an old bill has not been paid and start collection procedures to have the customer pay it.

Location of Former Customer

After deliberate efforts have been made by service representatives to take an application that is complete in every detail, and after the credit manager has required the maximum deposit permitted by the rules, further action must be taken against the customer who has incurred a large bill that he has not paid. Reminders, letters, and the efforts of telephone and field collectors may be in vain. As a last resort, if the amount of the bill is greater than the minimum established for legal action, the bill is referred to an attorney for collection.

Filing a lawsuit is very easy, but unless the former, delinquent customer is located and his assets discovered, a lawsuit serves no useful purpose. Locating a former customer is essential so that he can be served with the process of the court to make him respond to the court's orders. A former customer who has not paid his bill is usually not cooperative and generally does not voluntarily disclose his whereabouts. But very often he can be located.

Public Agencies

Postal service. The postal service can help locate a former customer in two ways. A letter is sent by certified mail with instructions that it be delivered to the addressee only, and that the receipt showing the address where it was delivered and the signature of the addressee be returned to the sender. The letter will be forwarded wherever possible to the former customer who is the addressee. The postal service also furnishes directory service in certain areas. A special card is sent to the former customer's old address; if he has left a forwarding address, the area post office will return the card showing the new address.

Department of motor vehicles. The department of motor vehicles has two divisions that will supply information: the division of drivers' licenses and the division of vehicle registration. From the former, information about the height, weight, age, and signature of the person to whom a driver's license was issued can be obtained. From the vehicle registration division can be obtained the address of the legal owner of a vehicle to whom the former customer may be making installment payments. If he is, the legal owner may have his latest address. If the former customer has complied with the law and notified the motor vehicle department of his new address, both divisions will have it.

County and city clerks. The county clerk's office has records of corporations, partnerships, or persons using fictitious firm names. The county clerk also issues licenses of various kinds in the unincorporated areas of the county.

The city clerk issues licenses within the incorporated areas of the city. He also maintains records of the ownership of all real property within the city limits, including the legal description of the property, the names and addresses of the persons to whom the property is assessed for tax purposes, and the address of the property. These records may not be up to date for the purpose of locating the former customer; although he might sell his property interest, the records are not changed until after the sale has been recorded.

County recorder. The county recorder's office has copies of all documents recorded in his office. Usually these documents pertain to real property. The documents are indexed according to name.

County assessor. The county assessor prepares the tax assessment roll listing the owners in alphabetical order, together with a description of property for which there has been an assessment for taxes as of the first Monday in March of each year.

Registrar of voters. The registrar of voters maintains an ever changing list of those eligible to vote. Although not as current as property records, the list contains descriptions of people, their signatures, and their latest ad-

dresses. In many instances, occupations are also listed.

Public welfare agency. Although the agency's information is treated as confidential, it has to disclose some of its information when calling a utility for assistance, as when an attempt is made to locate a person obtaining welfare benefits illegally. On a basis of reciprocity, information is exchanged, and both the utility and the agency benefit.

Public school system. The public school system is an excellent source of information. If the former customer has children of school age and has moved, the school system transfers records to the new school the children are attending.

Police department. Occasionally the police department can be of assistance in confirming that a former customer is in custody.

Private Agencies

Fewer private agencies than public agencies are available for furnishing information, but they can be very helpful in locating a former customer.

Other utilities. The service areas of the telephone, gas, or electric companies are not usually the same as that of the water utility, although there is considerable overlapping of areas. Usually a person who does not pay the closing bill of one utility will not pay the bill of another utility. When the former customer has moved, either to the service area of another utility or to a different area of the same utility, the utility serving him is interested in learning about his record of past payments. This utility will exchange information with the previous utility, disclosing the new address of the former customer, for information about his record of payments. The utilities currently serving a customer may not be able to collect a delinquent bill for another utility, but by demanding a deposit and coding this customer as a poor risk, they are able to minimize their own loss and make clear to the customer the consequences of failing to pay a utility bill.

Title company. Most information kept by a title insurance company relates to titles to land in the county, but the company also maintains information concerning the identity of persons interested in the particular property being served by the utility. The statement of identity usually required by the title company contains, among other things, a person's past residential addresses. If arrangements can be made to have access to these records, another valuable source of information is available to trace the former customer.

Credit and financial institutions. Other private agencies from which information is obtainable are the credit reporting services, such financial institutions as banks, savings and loan associations, or finance companies, and large businesses doing a credit or installment business. Credit reporting services, such as Dun and Bradstreet, are available for information on business ventures but usually cannot supply any information on a residential account. Some services specialize in supplying such information about individuals, but the cost of the service may outweigh its usefulness. Financial institutions usually deal with larger sums than does the water utility and are therefore interested in learning a great deal about their borrowers. Their application form may contain more detailed information than the utility's and may be helpful in locating the former customer.

Private persons. Private persons may be very helpful in supplying information. If a landlord has not been paid by the utility's former customer, he is also looking for the customer. The landlord may know the name of the firm that moved the customer or have other helpful facts. The customer's former employer may be able to supply an address to which he has sent a W-2 form, or a neighbor may be able to give the utility the new address.

Assets of Former Customer

When the whereabouts of the former customer has become known, it is necessary to locate his assets, which usually consist of his job and his home. If the former customer owns his home, information available from the title company becomes invaluable. The lot book shows the date of purchase, the amount of the encumbrances, and other matters of record, such as the homestead. An evaluation can be made of the equity. When the former customer tries to move from the area and sell his equity, an attachment lien or judgment lien obtained by the water utility usually must be paid before the title to the property can be transferred.

The most important asset of the former customer is his job, information about which should be on a well taken water service application. Usually arrangements to obtain payment can be made through the employer. The employee is more willing to cooperate when his employer is involved in the arrangements. If the former customer is employed by a large company, he can usually borrow money from the company credit union or other facilities set up to aid employees. If the customer has changed jobs, a check with his neighbors or his credit references may reveal the name of his new employer.

Legal Action

When the former customer is located and his place of employment is known, an effort should be made to persuade him to pay and avoid a lawsuit. He can be dealt with more easily at his place of employment, because he does not want to lose his job, and will usually make arrangements for installment payment of the obligation.

At this point, he should be made to sign both a "payment extension agreement," which provides for the payment of the obligation by periodic payments, and a "confession of judgment," which is used only if he fails to make the payments and which is the equivalent of a judgment obtained after a lawsuit.

If the former customer is still uncooperative, a lawsuit should be filed. If, under local law, the amount of the bill is large enough, a levy may be made on the salary or real property. Generally, mentioning this possibility brings an uncooperative customer to terms.

The action is filed in municipal court, which requires formal written pleadings, as distinguished from small-claims court, where the proceedings are informal. The formal pleadings are printed; space on the form is available for the name of the person being sued, the amount due, and the date of the closing bill. The forms are completed, signed, and filed. The court issues the summons, and the former customer is served with a copy of the formal pleading (the complaint) and the summons. Sometimes a writ of attachment is obtained from the court. This writ, together with instructions, is given to the sheriff. The sheriff, following instructions, levies on the

salary or the real property of the former customer.

The advantage of using the municipal court instead of the small-claims court is that the formal complaint requires a formal answer. The former customer seldom, if ever, files an answer. After he has been served with the copy of the summons and complaint, he has 10 days to file his answer. If he fails to answer, a default judgment is obtained against him. In the unusual case when an answer is filed, the matter is set for trial.

After the judgment has been obtained, an abstract of it, received from the clerk of the court, is recorded in the county recorder's office. This action results in a judgment lien being placed on record; the lien attaches to any real estate the former customer owns or will acquire within the following 10 years. The abstract is always requested and recorded, unless the former customer makes arrangements for payment. A writ of execution is generally requested when assets of the customer have been located, and a levy is frequently made on his salary. Very seldom is a levy made on his automobile, because usually more is owing to the legal owner than it will bring on forced sale. Before a levy is made on a business, the utmost caution should be used because of the expense and complications involved. A levy on a bank account, if the former customer has one, is very effective.

To avoid the unfavorable publicity of a forced sale of the home, a levy with a writ of execution is usually not made. The judgment lien generally provides enough protection, so that when a sale of the home is attempted, the judgment must be paid before the title can be cleared.

When the former customer does not have any discoverable assets, an order may be obtained from the court requiring his personal appearance in court. There, he is sworn and then may be questioned about his assets, his earnings, and his related activities. Frequently, the former customer, now the judgment debtor, does not care to be cross-examined about his activities and, consequently, becomes more cooperative. He makes arrangements for payment of the judgment rather than go to court, lose time from work, and discuss his private affairs in public.

The active pursuit of former customers to obtain payments of delinquent bills not only brings in a large percentage of the money sought but also helps to inform would-be debtors that vigorous efforts to collect bills will be made.

Bankrupt Customer

If a customer has filed a petition to be adjudicated a bankrupt, there is really little a water utility can do except to file a claim for the debt within 6 months after the petition is filed. The utility cannot discontinue future service because of the customer's failure to pay the past debt, which was listed in the petition and discharged. It can demand a deposit for future service or, if the bankrupt person is willing to pay the old bill, accept periodic payment on the old account after the date of discharge. The customer can demand, and must be given, water service if he complies with the rules, for, as far as the law is concerned, the unpaid water bill is discharged and wiped out by the bankruptcy as if it had been paid in full.

Deceased Customer

Another type of unpaid bill is one that survives the customer. This bill should be apportioned. For the services rendered prior to the date of death,

a formal claim must be filed with the executor or administrator of the estate; for the portion after the date of death, a bill should be sent to the executor or administrator as an "expense of administration." The formal claim has to be approved by the executor or administrator, then by the court. If the estate has funds, the claim will eventually be paid. The portion called the expense of administration has to be paid immediately.

Summary

Before legal action is taken against a delinquent account, the size of the bill and the overall situation has to be evaluated. The cost of the collection operation and the chances of collecting the bill must be kept in mind. If the bill is small, it may not be worth the cost of legal action. If the customer is a known bad risk, without assets, and on the public assistance rolls, legal action may not accomplish much. But in the greater number of cases, the customer usually can be forced to pay the bill. In these cases, legal action does result in recovering enough money not only to pay the expenses of maintaining such an effort but also to add a considerable amount to the revenue of the water utility.

Use of Microwave Radio in Telemetering

Harrison T. Randolph

A paper presented on Nov. 4, 1960, at the Chesapeake Section Meeting, Washington, D.C., by Harrison T. Randolph, Electrical Engr., Washington Suburban San. Com., Hyattsville, Md.

THIS article will discuss some of the problems, procedures, and equipment that should be carefully considered in laying out a short-wave or microwave telemetering system. Such systems are presently used in isolated areas, over great distances, or in very special situations where they have been found to be more practicable and economical than leased telephone wires.

At this time, microwave equipment comes at a very high first cost, but will undoubtedly drop considerably in price as more use is made of it. With these costs and the complexity of the equipment in mind, it should be emphasized that with a microwave telemetering system, special care is required in selecting the equipment best suited for a given application. FCC is now assigning frequencies in the microwave range of the spectrum for telemetering purposes, so the emphasis here will be on microwave rather than short-wave equipment.

As for telemetering, various systems have been in use for a number of years. The general function of telemetering is to provide a means of transmitting electrical signals from points of transmission to receiving points located at a distance. For example, the Washington Suburban Sanitary Commission at Hyattsville, Md., has systems by which pressures, flows, and temperatures are recorded, and through which pressure-reducing valves are remotely controlled.

In the early stages of telemetering, only one signal impulse was transmitted at a time over a pair of telephone lines because at that time the telephone company made a channel charge for each simultaneous pulse or function. In order to escape this charge, the early system made use of a sequencing unit that would transmit one function at a time over a pair of telephone lines, so that in the course of a few minutes, several functions could be transmitted over the same pair of lines in a predetermined sequence. In other words, the functions to be transmitted were separated mechanically by means of a sequencing or cam-timer arrangement at both the transmitter and receiver ends. Now, however, the telephone company leases a pair of lines and permits several functions to be channeled simultaneously at no extra charge. Hence, many of the more recent telemetering systems have employed audio tone (frequency) as a transmitting agent of the electrical impulses. In this system numerous audio tones can be sorted or filtered at the receiver, making simultaneous reception of several functions possible.

Properties of Microwaves

In a microwave telemetering system, the greater proportion of prob-

lems to be studied and resolved have to do with microwave frequencies as a transmission medium. Microwaves, as the name implies, are very short electromagnetic waves, which means that microwave radio frequencies must be correspondingly very high (the higher the frequency the shorter the wave length).

Because of the high frequency position occupied by the microwaves, and their close proximity to light waves (Fig. 1), microwaves in the frequency spectrum behave very much like light waves. Thus many actions and interactions that may be ignored in the lower frequencies become dominating factors when dealing with microwaves. In practice, microwave energy is guided by hollow tubes, or "waveguides" as they are called, with inner reflecting walls. This energy can be polarized by passing it through waveguides in a manner similar to that for light waves, which become polarized when passed through polarizing material. Waveguides rather than coaxial cable are used with microwave frequencies because their physical dimensions can be made comparatively small (usually half the actual wavelength), and the efficiency of the circuit is higher.

Because of the properties inherent in microwaves, conventional circuits cannot be used, and new circuits must be designed to take their place. It must be noted that no changes are made in basic radio theory, but that factors which were once thought of no importance and were therefore neglected must now be taken into account. It should also be noted that in almost all present applications, microwaves are encountered only at the last stage of the transmitter and the first stage of the receiver, although the major portion of the equipment is designed with more conventional circuits. Microwaves, like light waves, tend to seek a straight-line propagation path and can be focused, deflected and reflected. Thus it follows that the wave path, the area between the transmitter and the receiver antennas, is of utmost importance. In fact, the path for the propagation of the microwave must be surveyed and carefully determined if losses in the system are to be held to a minimum. Therefore, it is recommended that a propagation path survey be made.

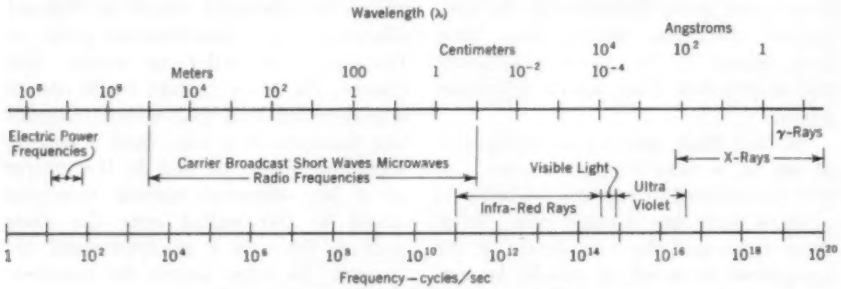

Fig. 1. Electromagnetic Frequency Spectrum

The proximity in the spectrum of microwaves to visible light is illustrated.

Fresnel Zone

The propagation path survey is made not only to avoid obstacles directly in

the line of sight between transmitter and receiver antennas, but also to insure that such obstacles are utilized to reduce interfering Fresnel zones. Fresnel zones are portions of energy radiations which can be indicated by a study of a particular microwave front at some point between the transmitter and the receiver. This study will show that the front may be divided into well defined zones that differ in electrical path lengths (from transmitter to receiver) by a half wavelength for each zone. Each point in this wave front is radiating energy toward the receiving antenna as well as in all other directions. Because the path length increases away from the center line, however, the phase of this radiating energy gradually shifts as the distance from the center line increases. Some portions of the wave front will radiate energy sufficiently out of phase at the receiver to contribute to cancellation of the energy of the main path. Those portions of energy radiations that are out of phase with the main path are said to be in the Fresnel zones.

To eliminate or reduce the effect of these out-of-phase radiations, the height of the antennas is raised or lowered to a point where the out-of-phase portions of the wave front will be obstructed by higher elevated surfaces situated between the antennas, or if none exists, by the earth's curvature. Thus the out-of-phase zones are cancelled and the resultant microwave signal is strengthened. It follows, therefore, that there is an obstacle proximity that

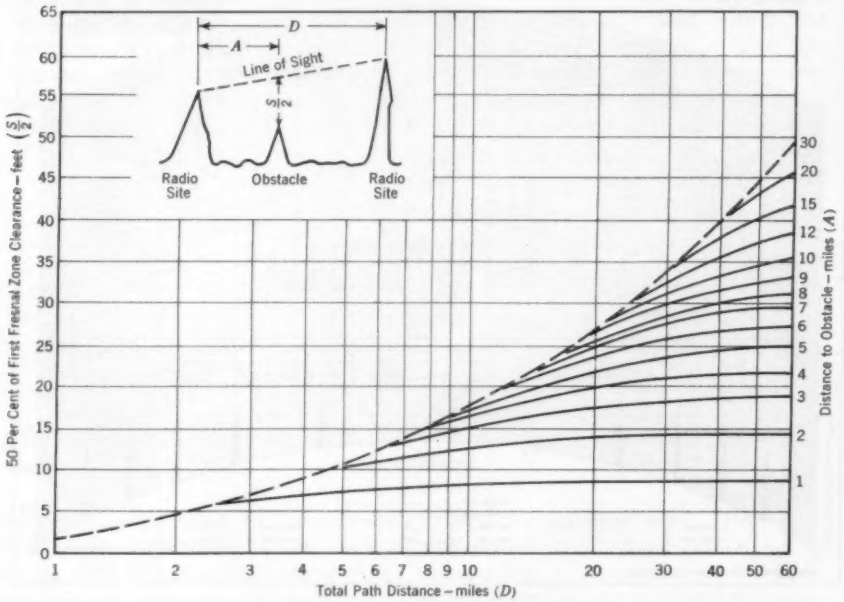

Fig. 2. Fresnel Zone Clearance Chart

Chart is calculated for 6,585 millicycles and is applicable over the range of 5,925–8,400 millicycles. Distance A *is less than or equal to Distance* D.

enables the signal at the receiver to be stronger than it would be if the beam were totally unobstructed. This point is called the "first Fresnel zone clearance," and either increasing or decreasing the antenna heights will result in a decrease of signal strength.

can be obstructed. When there are no hills or other obstructions, this wave is chosen at a point midway between antennas, where the obstructing object is the curved surface of the earth.

The energy close to the zone limit approaches being 180° out of phase,

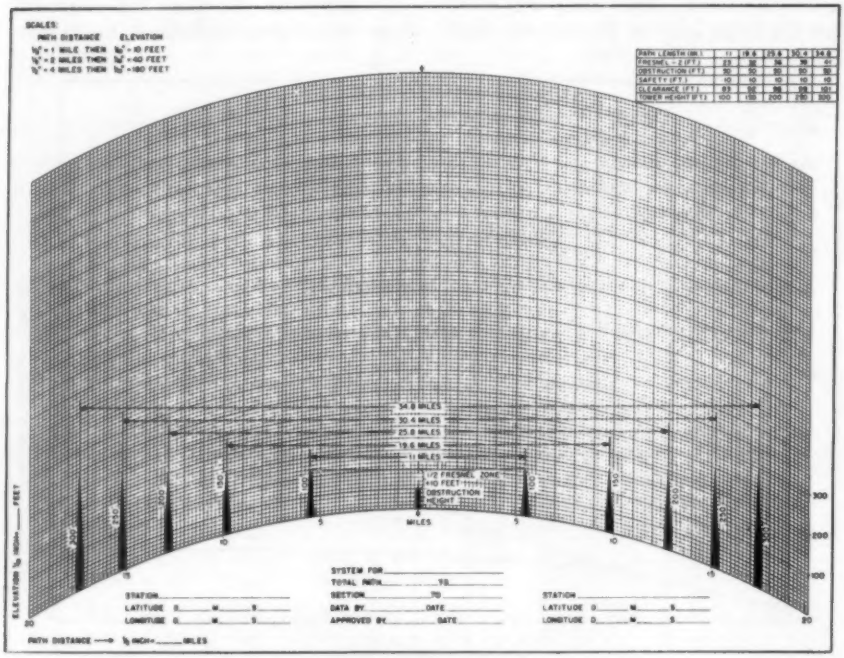

Fig. 3. Sample Profile Chart

The path distance corresponding to various heights is shown, assuming a 50-ft obstruction and perfectly level terrain.

The actual radius of the first and succeeding Fresnel zones depends on two factors: (1) the frequency involved—higher frequencies mean shorter distances from center line to the first Fresnel zone, and (2) the distance from the transmitter to the wave front being analyzed. In practice, this wave front is chosen to be the first one that

and contributes little to the signal strength, so about half of the first Fresnel zone must be cleared for adequate communication.

To insure proper clearance of the Fresnel zone and to accommodate for the other properties of microwave radiation, the practices and devices described below must be understood.

Propagation Path Survey

Microwave propagation path surveys provide: (1) information for preliminary cost estimates of a microwave system, (2) information for FCC, and (3) determination of tower heights required for proper Fresnel zone clearance.

A preliminary paper survey is usually made to determine the number of repeater stations and approximate tower heights required. From this information, the preliminary cost estimate can be made. The final survey establishes the exact site location and tower height as well as the information required for filing FCC construction permit applications. The necessity for clear line-of-sight transmission, with adequate clearance above all intermediate obstructions, is essential and must be established by this final field survey.

Contour maps are necessary in determining the station site and the tower height best suited for the job. It should be noted, however, that maps do not indicate such obstructions as high trees, buildings, and bodies of water, which in the final analysis could be the cause of high losses in the microwave circuit. Where pumping stations or water towers are already established, it is desirable and economical to use them to house multiplex and termination equipment and to mount antenna equipment on top of them where possible. But, whether the site is already established or to be determined, the propagation survey is a very important part of the engineering study. For example, the Washington Suburban Sanitary Commission presently has twenty stations from which operational data are collected by means of telemetering circuits. It also has numerous tanks located on comparatively high elevations throughout the district, some of which are favorably located for antenna sites. Just how well suited one location would be in comparison with another would have to be determined by making a propagation path survey.

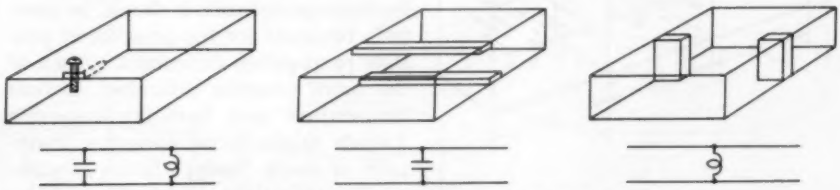

Fig. 4. Barriers in Waveguide to Control Reflection

The extent to which the screw projects into the waveguide determines the magnitude of the compensating reflection. Obstacles in the other two waveguides cannot be easily adjusted.

After plotting the location of each proposed or fixed site on a map, intermediate points, if required, are selected. Selection is based on determining the best topographical features and station accessibility by all-weather roads. Several alternative relay sites (tanks, if available) should be selected, and lines should be drawn from those locations to an adjacent fixed station. The elevation at prominent points along these lines is then trans-

ferred to true earth curvature profile graphs to obtain a profile of the proposed path. The profile should be plotted so that the center of the earth curvature graph is midway between the two sites. Approximate tower heights required can be established by drawing a straight line on the profile between the two station sites (assuming a reasonable obstruction height for the area and allowing half the Fresnel zone plus 10 ft of clearance over obstructions). Fresnel zone clearance may be determined from Fig. 2.

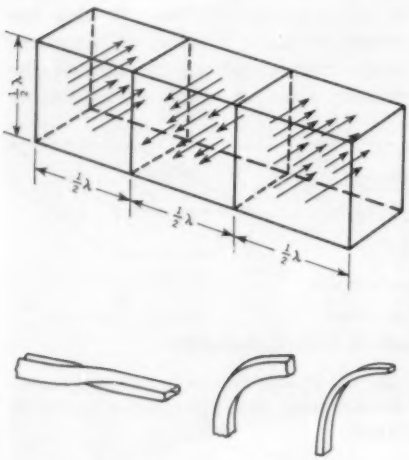

Fig. 5. Polarization and Twisting or Curving in Waveguide

Waves become polarized at right angles to sides of half their wavelength. A polarized beam will follow a gradual twist or curve in the waveguide.

After the above data have been plotted for several alternative paths, the path allowing minimum tower heights is selected. The highest location does not necessarily provide the optimum path, as the elevation of the terrain in the middle of the paths is generally more of a determining factor than the elevation at the terminal points.

The path length (with economical tower heights) over relatively level terrain will usually vary between 20 and 30 mi. The sample profile chart, Fig. 3, shows the path distance corresponding to various tower heights, assuming a 50-ft obstruction and perfectly level terrain. This sample chart is an aid in estimating tower height. The increase in tower height required for an increase in path length can be estimated by projection on the chart.

Obstacles and Difficulties

Once a path has been determined by these procedures, it should be carefully reviewed for the presence of possible propagation difficulties. Some of the more common difficulties include temperature and humidity inversion (which might cause excessive multipath or earth "bulge" fading), water surface reflections, and heavy antenna icing. Weather data for the area should be obtained and checked for the normal amount of rainfall, fog, and icing conditions. If low-lying fogs occur in the area (an indication of humidity inversion), an attempt should be made to estimate how often they occur and how long they may last. Under adverse conditions, it may be advisable to modify the path to allow more than half the first Fresnel zone clearance, or to relocate the path to a less disturbed area, if one exists. If a large body of water lies about midway between antennas, a reflection of the microwave signal could cause cancellation at the receiving antenna, but the reflection point must be visible from both antennas to cause trouble. It may be possible, by varying antenna heights or locations, either to shift the reflecting point to nonreflecting terrain or to inject a natural obstacle in the line-

of-sight path from antennas to reflecting point.

The following should be considered in making site selection: (1) accessibility, (2) power, (3) soil conditions, (4) building and construction problems, (5) cost of land, (6) zoning regulations, and (7) Federal Aeronautics Administration (FAA) regulations regarding airports and air lanes.

Availability of roads and power service is very important in determining the site selection, as costs of construction increase if either is not available. It is often more economical to add tower height (to a reasonable limit) than to build roads or long power service lines.

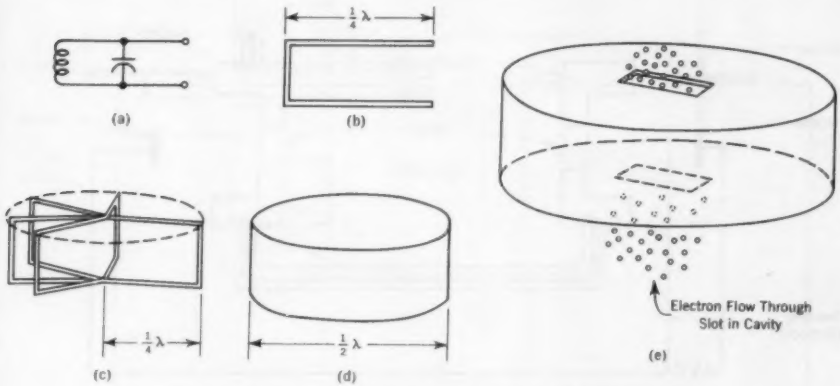

Fig. 6. Formation of a Resonant Cavity

Principles of a resonant cavity are explained in the text. Cavity may be used to oscillate electrons in a klystron.

Elevation Survey

The elevation survey of the intervening terrain can begin after a site has been selected and the location has been inspected. There are a number of methods for determining the elevation of pertinent points along the path. In the interest of speed and economy, however, most of the classical methods of surveying must be discarded. For average terrain, the use of surveying altimeters is the most practical method and will yield sufficiently accurate results. In extremely rough territory it may be necessary to resort to aerial surveys or vertical triangulation, but this discussion will be confined to the use of surveying altimeters, as these will suffice under most conditions.

The materials required to conduct a field altimeter survey are: (1) two surveying altimeters, (2) a complete set of contour maps, (3) a hand level, (4) a teleheight or hand transit, and (5) two mercury thermometers.

An altimeter such as the Survey Terra Altimeter,* or the equivalent is recommended. Instructions included with the altimeter explain the use of the instrument.

Both altimeters are adjusted to the known elevation at a bench mark location. One altimeter remains at the base elevation position (bench mark

* Model AA-1, made by American Paulin Systems Co., Los Angeles.

location), where readings of temperature and elevation are taken every 5 min. The other altimeter is taken by automobile and foot to prominent points along the path line. Readings of time, temperature, and elevation are recorded at each point, and the point is noted on the map. Data should be taken at a sufficient number of points to eliminate the possibility of higher intervening land. To avoid inaccuracies, any one series of readings should not exceed a period of 1 hr and a distance greater than 15 mi from the bench mark. When a series of readings have been completed, the moving altimeter should be returned to the bench mark location and again checked with the fixed altimeter. If the readings of the two altimeters do not check within 5 ft, the data obtained are inaccurate, and a new set of readings should be taken.

The bench mark location can be either primary or secondary. Primary bench marks have been previously established by federal or state survey crews, and the more prominent locations and approximate elevations are marked on the contour maps. For more complete and accurate information, a spirit-leveling publication is available from state authorities.

The required elevation and temperature readings may often be taken at points where the path line crosses roads or other points accessible by automobile. When this is the case, the altimeter may be observed in the car, provided it is not subjected to appreciable temperature changes. It is important that each altimeter remain at the temperature of the original calibration throughout any one series of readings. The automobile mileage indicator is very convenient for determining path positions. The distance from an intersection or other prominent point can be scaled from the map and used to determine the required path position. The highest elevation within 0.1 mi of either side of the path

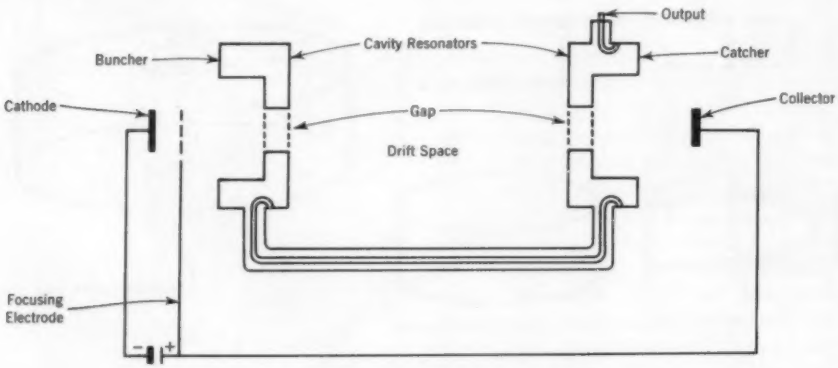

Fig. 7. Two-Cavity Klystron Oscillator

Although this type of klystron is more efficient than the reflex type, it is not as easy to tune.

line is the elevation that should be recorded. This wide path clearance permits minor site relocations and allows for slight map inaccuracies.

The height of any obstructions such as trees or buildings should be recorded at each point where readings of temperature and elevation are taken. Obstruction heights can often be estimated; however, if there is any doubt, during the time when minimum pressure changes are experienced. Exact hours for such conditions depend on the time of the year and the area.

Profile Plots

After the measurements have been assembled and the required corrections have been made, the elevation readings are plotted on true earth curvature

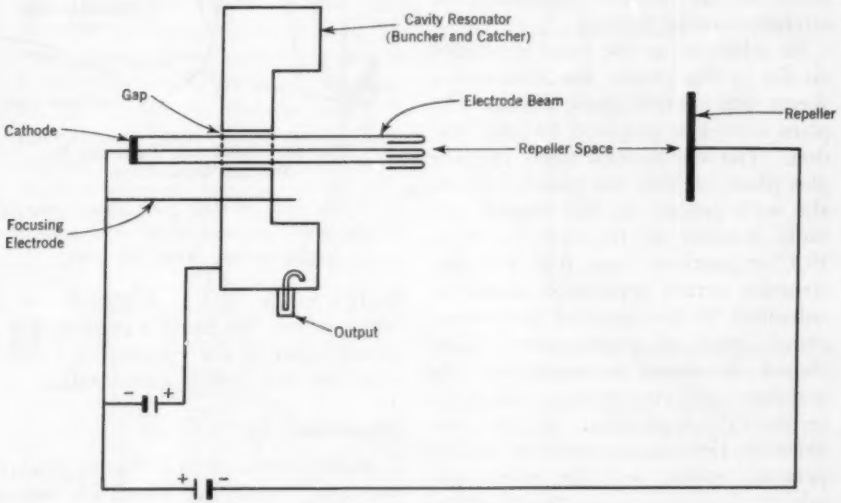

Fig. 8. Reflex Klystron Oscillator

This type of klystron has only one resonant cavity. Electrons are projected through cavity gap at repeller, return in bunches, resonate through cavity, and may be used to transmit radio frequency.

especially at prominent points, the obstruction heights should be checked with a teleheight or a transit. Altimeter readings should be made during the middle of the day. During the early morning hours and late in the evening, radical variations of pressure and temperature occur. As the altimeters are merely pressure-indicating devices calibrated in feet, readings should be taken profile paper. The obstruction heights are also shown on the profile graph because proper clearance is required above all obstructions. Tower heights required for a path line can be determined by laying a straightedge horizontally above all obstructions on the profile paper and allowing the required clearance (half the Fresnel zone plus 10 ft). Vertical lines projected from

the endpoints will then indicate the tower heights required. Refer to the sample profile chart, Fig. 3. Many combinations of tower heights can be obtained by this method. Since there are at least two paths emanating from each repeater station, the tower height will depend on both paths. Maximum tower use is obtained by trial and error. In the selection of tower heights, consideration should also be given to the FAA regulations for aircraft-warning lighting.

In addition to the data contained on the profile graph, site information sheets, site location maps, and site plot plans should be prepared for each station. The site location maps and site plot plans indicate the position of the site with respect to any airport and radio beacons as required by FCC. FCC regulations state that the construction permit application should be submitted 60 days prior to the contemplated start of construction. Care should be taken in answering the questions and requirements called for on the FCC application. In fact, considerable time can be saved by making personal contact with the proper authority in the FCC. A mistake of a word or two can cause a possible 2–3-month delay in the granting of a construction and station authorization.

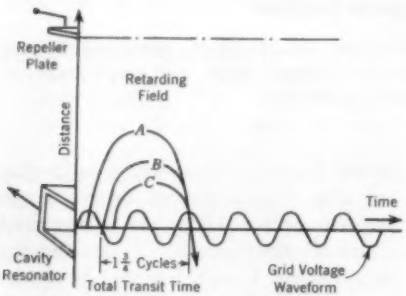

Fig. 9. Electron Bunching in Reflex Klystron

Although Electrons A, B, and C *are emitted at different times, they return to the cavity resonator gap at the same time.*

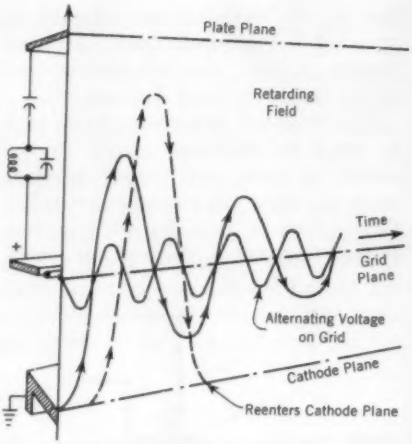

Fig. 10. Feedback Function to Sustain Oscillation

Electron with dotted path gives energy to the grid; electron with solid path absorbs energy from the grid.

Repeaters

Radio transmission in the microwave frequency bands is essentially short range, and for great distances some method for relaying the transmitted signal must be provided. Such relaying is done by what is known as repeaters. These repeaters are of two general types, active and passive. Active repeaters amplify the signals received and then reradiate them; passive repeaters reflect the signals, changing their direction, but do not amplify the signals. Some active types vary according to their use and method of operation. Two types are through-repeaters and terminal repeaters.

A through-repeater is the simplest type of active repeater. The signal is received and changed to an intermedi-

ate frequency which can be amplified efficiently. A second mixer is then used to increase the frequency to the desired output carrier frequency. This is then amplified and transmitted.

A terminal repeater station is one in which all signals are completely demodulated and repeated by remodulation. In its simplest form, it consists of two complete terminal assemblies, the receiver output from one feeding the transmitter input of the other through multiplexing equipment.

In the passive-repeater group, two types of reflectors are used, depending on the terrain or obstacle which the microwave beam must be reflected around. The plane sheet reflector is used wherever possible. When a ridge intercepts the beam, or a situation exists such that a plane sheet reflector is not adequate, two parabolic reflectors must be used, one facing each repeater station and connected together by means of a waveguide or coaxial cable. The passive type of repeater is used at locations where the terrain makes maintenance and inspection of the repeater station difficult. A passive repeater should only be used on very short hops, where attenuation and beacon bending cannot have any serious effect.

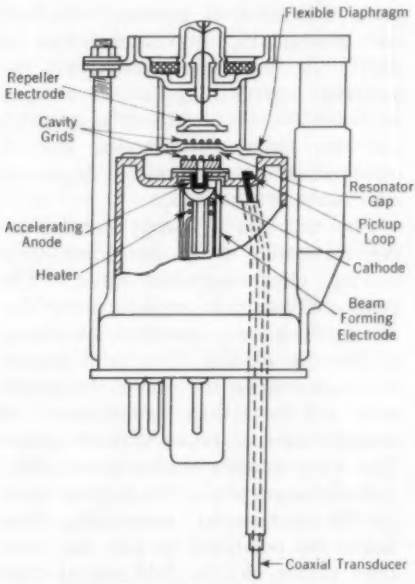

Fig. 11. Resonator Cavity in Actual Klystron

Cavity is toroidal, not cylindrical. Radio frequency is carried from klystron by coaxial transducer.

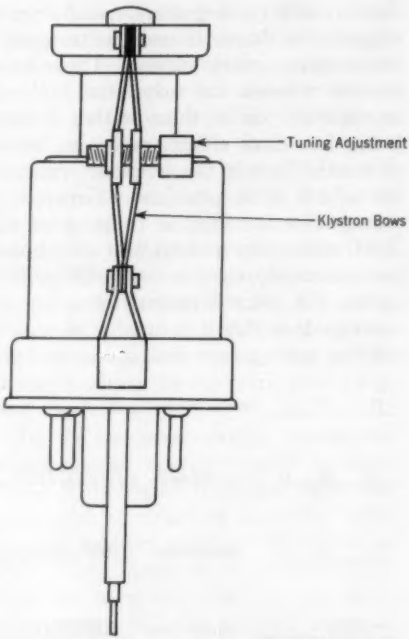

Fig. 12. External Bows on Klystron for Adjustment of Repeller Spacing

Adjusting the repeller spacing or the repeller voltage will change radio frequency produced.

Propagation of Microwave Energy

At microwave frequencies, the parallel-wire transmission line is not satisfactory. Instead, a hollow con-

duction tube (waveguide), usually rectangular in shape, is used to transmit the electromagnetic waves. There are several reasons for using the hollow waveguide; one of them is that it has lower loss than either open-wire lines or coaxial lines in the frequency ranges for which it is practical. Generally, waveguides are used at frequencies of 3,000 millicycles and up, and wire lines are commonly used below 3,000 millicycles. A second reason for using a waveguide is that it is capable of transmitting more power than a coaxial line

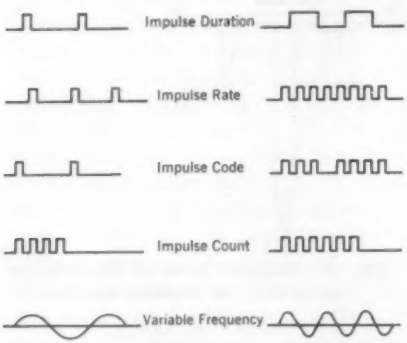

Fig. 13. Telemeter Coding Schemes

With coding schemes, several messages can be transmitted simultaneously.

of the same size. Third, the reflections within the waveguide can be controlled by an adjustable, screw-type, impedance-matching system that eliminates reflected waves (Fig. 4). The extent to which such a probe (or screw) projects into the waveguide determines the magnitude of the compensating reflection, while the position of the probe with respect to the standing wave pattern, which is to be eliminated, determines the phasing of the reflected wave. The adjusting screw becomes resonant when the equivalent penetration of the screw is a quarter wave length.

The other two examples shown in Fig. 4, of obstacles used in waveguides to introduce reflection, cannot be conveniently adjusted by experiment; they can be used only in waveguide systems where a reflected wave of known and unvarying character is to be neutralized.

One disadvantage of the waveguide is its minimum frequency restriction, called the cut-off frequency, below which no other frequencies can be transmitted. As a result of this characteristic, a rectangular waveguide would have to be wider than 2 in. to transmit a 3,000-millicycle signal, 20 in. wide for 300-millicycle signal, and 17 ft wide for 30-millicycle signal. If the waveguide dimension is less than half the wavelength, the attenuation becomes very great, but if the waveguide dimension is greater than half the wavelength, the attenuation is slight. A waveguide must have a dimension approaching a wavelength in order for the fields to propagate, and this limits the practical use of waveguides to extremely high or microwave frequencies.

The microwave energy carried by the waveguide is in the form of a moving electromagnetic wave. The field configuration travels along the waveguide axes in the direction shown in the top of Fig. 5. As it travels a distance down the guide, the amplitude will be reduced as a result of energy losses in the walls of the guide. The wave consists of electric and magnetic fields perpendicular to each other. In the rectangular waveguide, these fields are polarized in that the force lines of the electric field are at right angles to the side of half the wavelength. If a waveguide is made to twist or curve gradually, the polarized beam will follow the twist or curvature as in the bottom of Fig. 5.

Generation of Microwave Energy

With microwave frequencies, conventional oscillators, which are basically frequency generators, become inefficient, and new systems must be used to produce oscillations at these high frequencies. One type of oscillator that has been developed for generating microwave frequencies is the klystron. Two main categories of klystron oscillators are the reflex and the two-cavity klystron. Actually, the reflex is a modified version of the two-cavity klystron, and is very similar in operating principles.

The reflex klystron is less efficient than the two-cavity klystron because a single resonator performs both the function of bunching and the function of catching. On the other hand, with a single resonator the ease of electrical tuning by varying the repeller voltage makes it better for use when only small amounts of power are required. Another advantage of the reflex klystron is its greater stability as compared with the two-cavity klystron. Thus the reflex klystron is preferable, and it has been particularly satisfactory for use in the frequency range 1,000–25,000 millicycles.

The heart of the microwave energy generation system is the oscillator, so it should be given more than passing interest. A brief description of its vital components and electronic functions will be given special consideration.

The basic components of this oscillator are termed the resonant cavity, the buncher cavity, the catcher cavity, the anode, the cathode, and the focusing electrode.

Resonant Cavity

A resonant circuit, Fig. 6a, exists when inductance and capacitance are equal. As shown in Fig. 6b, a closed and parallel line of quarter wavelength makes a resonant circuit. Any number of these parallel circuits can be added as shown in Fig. 6c, and as long as the radius is kept exactly a quarter wavelength, the circuit will remain resonant. Actually, if a lot of these parallel resonant circuits were added, it could be readily seen that they would take the form of a circular can or tank, as shown in Fig. 6d. This flat can is called a resonant cavity. A slot or gap is cut in the middle through which the electrons pass (Fig. 6e).

In the resonant cavity, as in any tuned circuit, energy applied momentarily is oscillated back and forth between the electric and magnetic fields as each in turn continues to build up and collapse until all of the initial energy has been used through the resonant cavity. It follows that if by some means more energy could be supplied at exactly the right instant, the energy in the cavity would be sustained, which in turn would sustain the oscillations. To accomplish this, several oscillators have been devised, one of which is the klystron type.

Klystron Oscillator

In the klystron type of oscillator is a tuned resonant cavity with a slot or gap in the center of it. Figure 7 shows the two-cavity klystron, and Fig. 8 shows the reflex type of klystron. A beam of electrons from the electron gun or cathode causes these electrons to flow through the gap. As the electron beam passes through the gap in the resonant cavity and enters the repeller space, the forward motion of the electrons is opposed by a negative voltage that causes them to slow down, turn back on themselves, and reenter

the gap in the resonant cavity. This process of slowing the motion of the electron is known as velocity modulation. The electron beams passing through the gap for the first time and entering the repeller space have different velocities, because the modulating action of the radio frequency voltage is present in the resonator cavity. This causes the electrons to return from the repeller space to the gap in bunches. A representation of this bunching function is shown in Fig. 9.

In this figure, Electron *B* is the reference electron. Note that it passes through the gap exactly when the gap voltage is zero and just going negative. *B* follows a parabolic path. The action here is similar to a ball thrown upward and returned to earth by the force of gravity. In this case, however, it is the repelling force of the negative magnetic field within the repeller space that causes *B* to turn back on itself and move toward the gap from which it was propelled. Consider now Electron *A*. This electron passed through the gap just before *B*; whereas the voltage across the gap for *B* is zero, the voltage across the gap for *A* was at a maximum, and it accelerated *A*. Thus *A* entered the repeller space with greater velocity than *B* does, and consequently *A* penetrated farther into the repeller space. As a result, it took *A* longer to return to the gap than it does *B*, so *A* arrived back at the gap at the same time as *B*, because its head start was compensated for by its increased transit time. Unlike *A*, Electron *C*, which will pass through the gap later than *B*, will emerge from the gap with less force than *B* or *A* because it will encounter a more negative or retarding field across the gap than either of the others encountered. *C* will thus return to the gap at about the same time as *A*. This is because the late start by *C* will be compensated for by its shorter transit time.

Therefore these electrons return to the gap at the same time, and pass through it in bunches. As they pass through the cavity for the second time, they give up some of their energy to the cavity and are then stopped by the cavity, which functions as the collector (Fig. 10). This bunched flow of electrons is repeated with each cycle of radio frequency. To summarize, electrons are constantly beamed through the gap, are bunched, and give up energy to the cavity.

The resonant cavity actually used in the klystron is not a cylindrical but a toroidal one which can be tuned by adjusting the repeller space between the repeller electrode and the gap (Fig. 11). The toroidal cavity is formed by bringing the grids of the cavity closer together. The transit time of the electron inside the cavity is increased as the space between the grids is decreased. In the klystron this grid spacing is accomplished by flexing the external bows which mechanically change the spacing of the resonator gap (Fig. 12). Reducing the gap spacing increases the capacity and thereby lowers the tuned frequency of the resonant circuit.

The frequency can be changed by varying the repeller voltage. The more negative the repeller voltage is, the earlier will be the return of the electrons to the gap or grid, and the less negative the repeller voltage is, the longer will be the return; hence, the more negative the repeller voltage is, the higher the output frequency will be. For that matter, any variation in the magnitude of the electron beam or of voltages that would vary the transit

time of the electrons will result in a frequency change.

Multiplexing

There are two general types of apparatus used in microwave communication systems: radio equipment and multiplexing (channeling) equipment.

Multiplexing is a system by which various messages can be transmitted simultaneously. The multiplex equipment imposes voice and signaling channels on the microwave beam. With this method it is possible to separate completely the voice and signaling systems in telemetering or load control systems. Two general methods of translating the measured telemetered data over a microwave system via multiplex are frequency division and impulse time.

Frequency division is accomplished by separating the various messages to be combined so that each message is limited to a certain frequency range with no overlapping between ranges. This is done by first limiting the audio band width to define values.

In the impulse time, each message is transmitted for a period of time in regular sequence. Figure 13 pictures five different forms generally followed in the translation of measured data into a pulsed or sinusoidal voltage. In the impulse type of telemetering, the data can be in the form of open and closed contacts or in the form of on-off or reversed current keying. Frequency type of telemetering provides a low-level sinusoidal voltage varying in frequency. The following describes the coding schemes illustrated in Fig. 13:

1. *Impulse duration*—metered data is proportional to pulse length with pulses at a constant repetition rate.

2. *Impulse rate*—metered data is proportional to pulse repetition rate with pulses of constant pulse length.

3. *Impulse code*—metered data is indicated by the total number of pulses per reporting time interval with pulses of constant pulse length at a varying repetition rate.

4. *Impulse count*—metered data is indicated by code signals consisting of specific configurations of pulse and the spaces between pulses.

5. *Frequency*—metered data is proportional to the frequency of a subaudio sinusoidal voltage.

Microwave Cost

Telemetering equipment already installed in an existing plant can be used, and its telemetered data channeled into a point-to-point multiplex radio system. With this system, a saving can be realized from the continued use of existing equipment. Several manufacturers have equipment on the market suitable for such hookups. The best procedure for obtaining this equipment is to call in several of the interested manufacturers and determine which of their equipment best fits the particular scheme presently installed.

Conclusion

Several components and considerations go into a well stabilized microwave telemetering system, but a path propagation survey and the careful selection of oscillators and multiplexing equipment are vital to a satisfactory system. The author believes that a careful study of these factors will bring into consideration all the other necessary components.

Telemetering for Small Utilities

Alfred W. Jorgensen

A paper presented on Apr. 14, 1961, at the California Section Meeting, Santa Barbara, Calif., by Alfred W. Jorgensen, Utility Supt., Monrovia, Calif.

TELEMETERING of some large utilities has been combined with automation and data processing to the extent that the control centers look like a missile center at Cape Canaveral. Philadelphia has spent $432,000 on its new electronic load control communications center, which is the heart of a network of electronic sensing devices, telemetering instruments, and microwave towers. These provide information on water flows, pressures, and levels at 120 points in the city's water distribution system. Data are picked up automatically from reservoirs, pumping stations, water mains, and other key points, and are flashed instantly through the microwave communications system to the control center.[1]

This example indicates the progress that has been made in telemetering and automation, but it is not typical of small water utilities. Some comparison should be made to show why nearly all water utilities are classified as small when compared to electric, gas, and telephone utilities.

Utility Size

There are more than 18,000 public water systems in the United States. Of this number, 86.4 per cent serve less than 5,000 people, and 93.3 per cent serve less than 10,000 people. All but 2.7 per cent of the 18,000 utilities serve less than 25,000.[2]

For another comparison to show this difference in size, Los Angeles County has only seven electric, four telephone, and three gas utilities, but approximately 335 water utilities. This again illustrates that most water utilities are small.

Automation

The purpose of this article is to indicate what telemetering can do, how it can help save money, and what can be expected both in the way of data available and in maintenance problems. The terms "automation" and "telemetering" are used interchangeably by many, but they are not the same. A system may have automatic starting and stopping of pumps from distant reservoir float controls. This is not telemetering; it is automation. The system may only have equipment at a central point where reservoir levels are recorded and indicators show when the pumps are running. This is telemetering with no automation. There are also many combinations. Radio transmission and signals transmitted over leased telephone lines are both used in telemetering systems, but in this article only wire communication is considered.

The telemetering phase from an operator's viewpoint, not from a technician's, will be especially considered. In most cases, the operator does not have the background or the knowledge

of the technical aspects of this type of equipment, but he knows what he wants to accomplish.

Telemetering Need

The need for telemetering is based on economic principles. Some say that savings realized will pay for the equipment, plus the total installation cost, in less than 3 years.[3] Others say the cost of telemetering is not justified except in special cases.[4] Savings can be made in the following costs: (1) labor of distribution system operators, (2) automotive equipment, (3) energy costs, and (4) capital costs.[5]

Another justification for installing telemetering equipment is the need for more and closer supervision of all important operations. By having all of the basic system data in one centralized location, weaknesses in the system such as low pressure, insufficient storage, or pumping capacity are shown immediately. Permanent records are then available indicating conditions as they were throughout the various parts of the system. These records can be analyzed and appropriate action taken to correct the deficiencies.

Very few small utilities can say they have nearly perfect records. Record keeping can be improved greatly with a telemetering installation that provides the following information: (1) reservoir levels, (2) well pump operations, (3) booster pump operations, (4) pressures at various points in the system, (5) temperatures of critical bearings, (6) room temperatures, (7) chlorine residuals, (8) automatic and regulating valve positions, and (9) rates of flow.

The most obvious need for telemetering is for handling emergencies. Most small water utilities have less than one maximum day's supply of storage, which means that the system has to perform nearly perfectly to provide adequate service.

Alarm System

An alarm system indicating high and low water in the reservoirs can be incorporated into the centralized telemetering center to warn immediately of a low level, so that necessary action can be taken before a real emergency occurs. The alarm system can also warn of power failure and signal failures. When a pump fails, the utility is not in immediate trouble if it is an open system with some storage. The trouble begins when there is little or no water. It can be said that an operator is not really in trouble unless he has too much or too little water. This is the reason for including high and low water levels into the alarm system.

The National Board of Fire Underwriters has recognized the importance of telemetering in the water supply section of its grading schedule. It has been calculated that a good telemetering system in a small utility with a small amount of storage could reduce its number of deficiency points from 100 to 25 (170 points represents an entire class for grading purposes).

Before deciding about any particular type of telemetering equipment, the operator should make an extensive survey to determine what functions he wants to control and supervise. Remote control of pumping operations is possible, but is it justified? The greater the distances to pumps, the more justification for remote control. Some operators only visit and inspect pump stations once a week; others are contemplating inspections only once a month. Many still believe in a daily check. The operator should consider every possibility, including expansion.

The main point is that any system finally adopted should work *for* the operator and not the reverse.

Some utilities plan project specifications that require manufacturers of equipment to have, first, a background of experience with similar equipment in the immediate area performing satisfactorily, and second, to have a service engineer available.[6]

Fig. 1. Telemetering Control Panel

Operators watch reservoir level indicator charts and pump indicator lights.

Location of Controls

The operator must decide where he wants to locate the centralized telemetering controls. It is possible to locate them in special rooms or buildings, at existing pumping facilities, or in the main office of the utility. The latter has many advantages from a public relations standpoint. This type of equipment is the most modern item in the water utility industry today. If this complex equipment is readily visible to the general public, the impression that the utility manager is merely the "village pump man" will disappear rapidly. Another advantage to having controls in the main office is to show that operating a water utility is not as simple and free from problems as many now believe. Others then share the knowledge of various operational problems. These instrument and control panels can be designed so that they can be moved easily. They need no special power circuits. An ordinary 120-v lighting circuit is sufficient, along with provisions for several telephone circuits. From a practical viewpoint, 20 functions can come in on the same pair of wires, although 26 is maximum. This keeps the cost of leased lines to a minimum, as the telephone companies charge by the distance involved and not by the number of functions.

Guarantee and Maintenance

Another important factor for the small utility operator in the design and installation of his telemetering system is whether he receives a "guaranteed" system. It is most important that a 1-year maintenance guarantee be included in the contract, and that this 1 year be defined. It should be understood that the guarantee period begins from the date of acceptance or from the date of the last "major" repair. This definition is quite controversial, as major and minor repairs may be interpreted differently. The definitions should be spelled out so that both the utility and the supplier understand the terms of the guarantee.

Maintenance of telemetering equipment is one of the reasons that many small utilities hesitate to use the equipment. During the installation, however, one or more of the utility's men can be assigned to work with the installer. In this way, much valuable information and many techniques can

be learned. Some equipment manufacturers have training programs for utility personnel, enabling them to make minor adjustments and repairs.

Anything mechanical will have defects in it, including telemetering equipment. Therefore, the utility should expect a certain amount of trouble during the first year of operation. This usually comes within the provisions of the guarantee so repairs and adjustments are made by outside personnel. This first-year trouble appears to be normal. Again it is helpful to have trained personnel of the utility available to take care of the minor adjustments. Some of the normal maintenance includes replacing burned-out light bulbs, changing defective transmitters and receivers, adjusting level indicators periodically, replacing oxidized mercury switches,

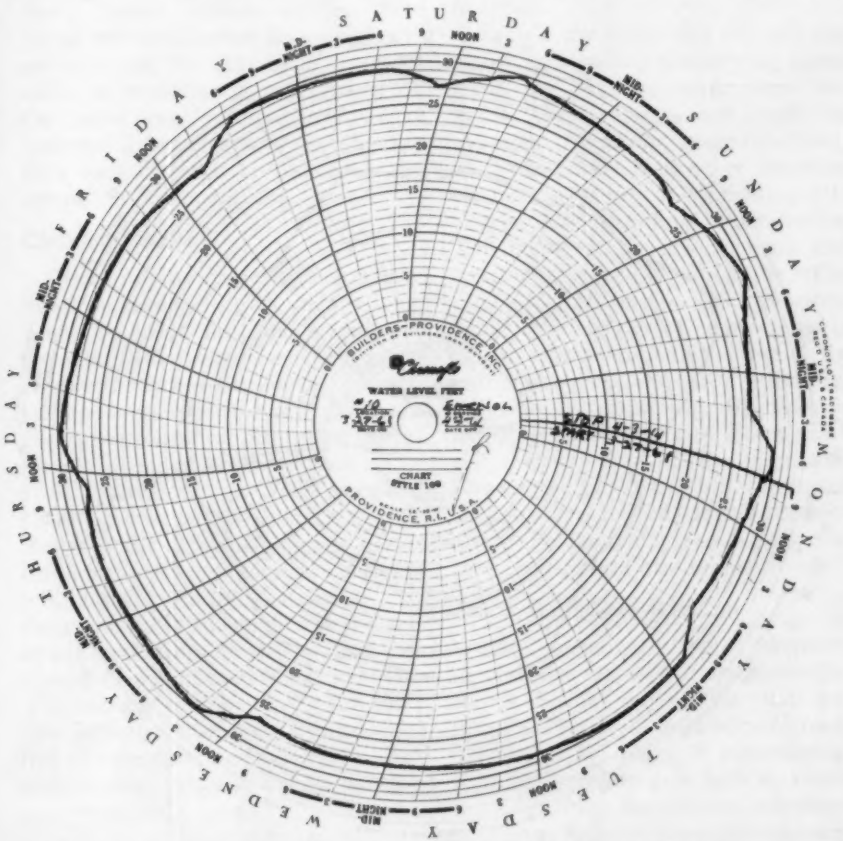

Fig. 2. Recording Chart for Reservoir With Automatic Pumps

Chart shows levels for 7 days. Pumps for reservoir were automatically turned on and off at predetermined levels.

adjusting volumes of signals so that indicator lights work properly, and periodically testing all alarm settings. Weather presents another maintenance factor, and telephone lines must be periodically checked with the cooperation of the telephone company.

Alarm Circuit

Another feature that helps save money and time and actually provides better supervision of the system is to have a "double-throw" switch on the alarm circuit. By this method, the utility personnel receive the alarms directly only during normal working hours. At night, on weekends, and on holidays, the alarm signal can be transferred to the police or fire departments who are on duty 24 hr a day. On receiving an alarm, the police or fire department dispatcher contacts utility personnel who decide what to do after analyzing the master monitoring panel

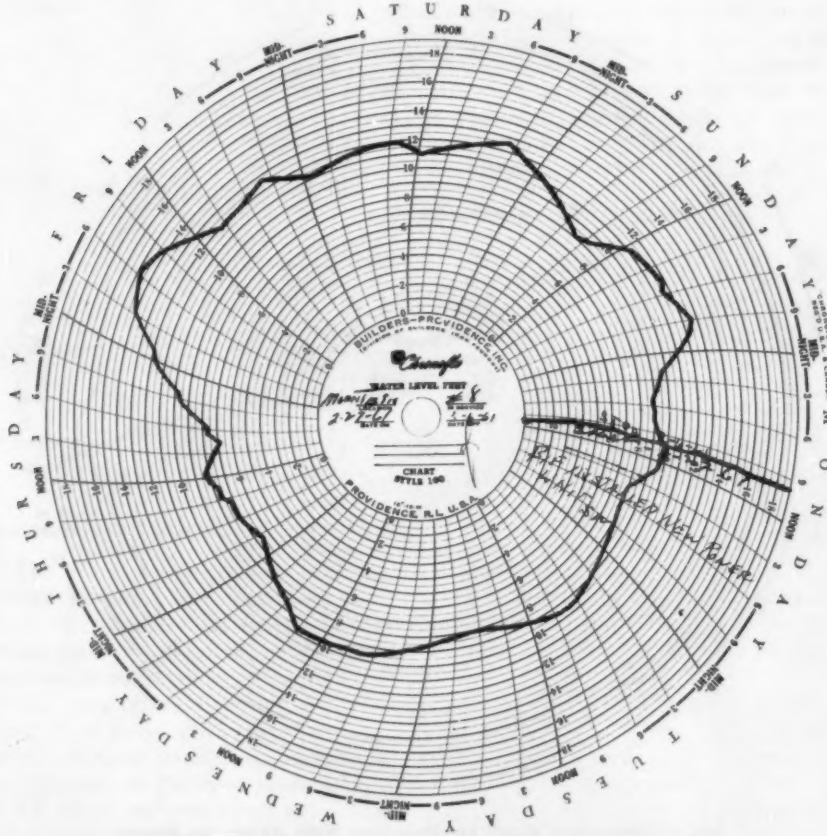

Fig. 3. Recording Chart for Reservoir With No Automation

Chart shows fluctuating levels, indicating no automation and poor operation.

(Fig. 1). This provides 24-hr protection without having two extra shifts.

The operator can expect some calls in the middle of the night because of malfunctioning equipment or, if the system is not fully automatic, because of errors in judgment by the system operators.

Another possibility that the utility operator should consider is the failure of indicator lights. Some design engineers recommend a 10 per cent brilliancy feature. Others say that there is not enough contrast between the 10 per cent and the fully lit lights, especially in sunlight. A test switch on the panel could immediately detect indicator light failures. The lights are then completely on or completely off during normal operations.

Circular Charts

Circular 7-day recording charts have many advantages over strip charts. They are easily read and stored, but more important, they provide a ready reference without causing an investigator to unroll a strip chart. They are also easier to use for comparing operations of one week with another.

An example of how 7-day recording charts on reservoir levels tell a story is shown in Fig. 2 and 3. Figure 2 indicates that perfect automatic operation took place. Figure 3 indicates that there was a wide fluctuation in the reservoir levels from day to day, and that apparently no automation was involved. This actually was the case. The chart also indicates that poor manual control of operation was a factor. With telemetering, this was known as soon as it happened.

Costs

Initial costs of telemetering systems can vary widely. A small utility, however, could bring into a centralized location key reservoir levels, show which pumps are on and off, and include the most important feature, an alarm system, for a cost of $10,000–$20,000. Each situation is unique, so each would certainly have to be studied to see what equipment would be most adaptable. Of primary importance is that the costs are not prohibitive, and that there are many firms available to design and install these facilities.

Even if the utility did not save any money by installing telemetering equipment, the increased supervisory control of the system is well worth the expense. Knowing reservoir levels, pressures, flows, and other functions can be a great help in eliminating deficiencies and providing better service. The public is demanding more and better service, and it is up to the utility to provide this service. The improved public relations cannot be measured in dollars and cents, but its value to the utility is equally important. The installation of telemetering facilities is probably more important to the small water utility than to the large one, because the small operator has limited storage and limited standby equipment. By improving supervisory controls, service will also be improved.

Automatic Meter Reading

There is another phase of telemetering for the future that has been discussed briefly during the last few years.[7] This is the possibility of reading meters by means of telemetering. Readings could be sent back to a central office over the existing telephone lines from each residence and commercial unit. The telephone company states that it would be capable of handling its part of this new concept if

the meter and instrument manufacturers could produce competitively priced transmitters for each meter.

There are other possibilities, such as incorporating gas and electric meter readings over the same pair of telephone lines. Nearly every home in the urbanized area has a telephone, so no new circuits would be involved. The current range of costs for reading water meters varies from 5 to 20 cents per meter. This is probably true for the other utilities as well. If the total telephone costs could be split three ways, therefore, the idea might be economically feasible.

Another possibility for telemetered readings is automatic billing, which would eliminate more of the labor costs of operation. As labor costs increase, this completely telemetered system will become more attractive.

Summary and Conclusions

The small water utility has a greater need for telemetering than large utilities because of the lack of storage and standby equipment. The small operator has to have his system operating nearly perfectly at all times to provide adequate service, so he needs all the supervisory controls he can justifiably install. Even if there were no savings involved, the increased knowledge of system characteristics, potential emergencies, and the new image of the water utility created in the mind of the consumer are well worth the expenditure.

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Rupture Control in Gas Pipeline From Corning to Eureka, California

James H. Stannard Jr.

A paper presented on Oct. 26, 1960, at the California Section Meeting, Long Beach, Calif., by James H. Stannard Jr., Gas Engr., Pacific Gas & Electric Co., San Francisco, Calif.

IN the 1940's, a booming lumber industry and a general acceptance of natural gas raised the demand for gas in California's Humboldt County above the local resources of the author's company to supply it. The company limited the service area, but consumption within the area increased, and potential customers requested that the service area be expanded.

The company had been supplementing a limited natural-gas supply from the nearby Tompkins Hill field with propane-air. Expansion of the propane-air equipment appeared necessary not only to meet the new demands but also to replace the capacity of the local natural-gas sources which were rapidly being depleted.

Early in the 1950's, however, a number of new natural-gas fields were discovered in the northern Sacramento Valley. The most promising of them was in the Beehive Bend and Perkins Lake areas west of Chico.

This ready-made and growing service area, the new supply of natural gas, and a company-owned power plant capable of burning either oil or gas—all making possible a reasonably high load factor—led to the company's decision to build one of its most challenging pipelines. Although the company has a number of lines that are both larger and longer, including the 34-in., 500-mi "Super Inch" main from Topock on the California-Arizona border to Milpitas in the San Francisco Bay area, the 168-mi, 12-in. pipeline to Eureka traverses some of the most difficult terrain yet to be encountered by the company.

Problems of Pipeline

As Fig. 1 illustrates, the pipeline runs from a point near Corning north to Red Bluff, thence west across the Trinity Mountains to Fortuna, and north to Eureka. Not only was the crossing of the Trinities difficult to construct, but the mountains also posed a problem for pipeline patrol and maintenance. The mountains lie generally in a north-south direction as a series of ridges. For a distance of 110 mi, the main is in hilly and mountainous country. For about 60 mi, the main is between 3,000 and 5,300 ft elevation, in a region where winter snows occur, rainfall is heavy, and earth slides are not uncommon.

The only access to about 80 mi of the main is from the company's pipeline road, which is as much as 6 mi from the nearest public road. The few public roads in the area are generally one-lane, unpaved, mountain roads. Access to the pipeline for routine patrol and maintenance is at times a real problem, and access for emer-

gency maintenance and repair may be extremely difficult.

As the rapidly developing load in the Eureka area outstrips the limited propane-air capacity, the single pipeline will become the only adequate source of gas. A major break in this pipeline would therefore seriously jeopardize the company's ability to maintain continuous service.

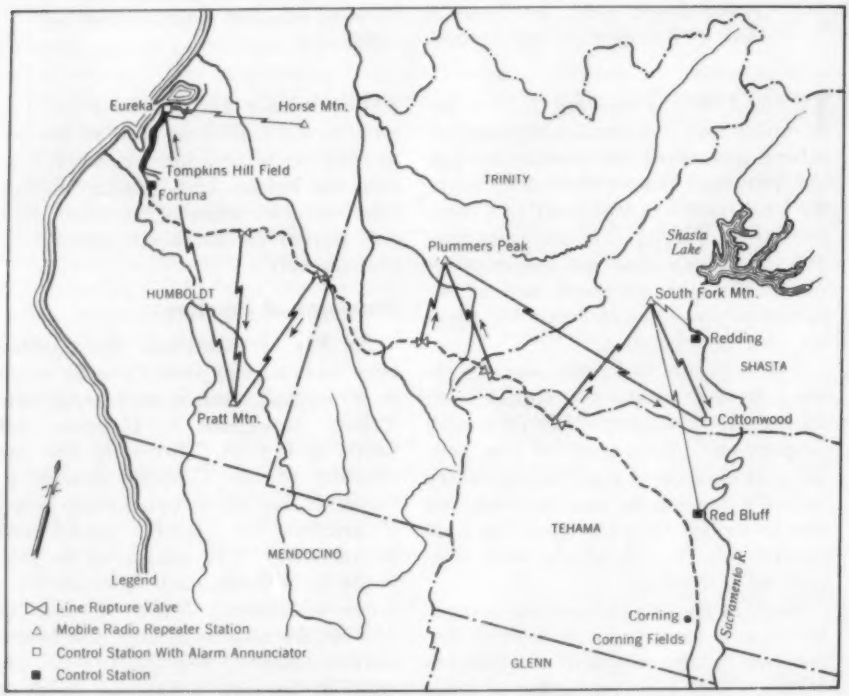

Fig. 1. Route of the Corning-Eureka Gas Pipeline

The 168-mi pipeline crosses the Trinity Mountains as it carries gas from the Sacramento Valley to the coast.

Importance of Quick Repair

The water and gas industries share an enviable record for continuity of service. Both can point to this record with pride. In addition to a natural desire to spare customers the inconvenience of an outage, the gas industry has a real economic justification for maintaining this record. An outage in a community, or even a small section of a community, is a matter of serious concern, not only because of lost revenue, but more importantly, because of the cost of restoring service.

The normal procedure in the event of an outage is to visit the premises of every customer, shut off the individual services at the meter, repressure the distribution system, and then revisit

every customer to purge house lines and relight appliances. A recent survey in the company's system indicates that the cost of restoration after an outage would be approximately $4 per affected customer. Obviously, the company could afford to pay a considerable premium to insure against a transmission line break that might cause an outage affecting the 19,000 customers in the Fortuna-Eureka-Arcata area.

Like a water system, which often has distribution reservoirs and hilltop storage tanks to provide for peak-hour demands and emergency supply in the event of source failure, the Eureka system has storage in low-pressure holders, propane-air production, and—of major importance—the line pack (usable volume of gas) in the pipeline itself. The combination of this storage, coupled with the local natural-gas production, is not adequate to sustain the area for prolonged periods. It is therefore essential that any line break be isolated without delay, so that as much pack as possible may be preserved.

To illustrate this point, a break is assumed to have occurred at approximately the middle of the Corning-Eureka line. It is possible to close only the valve downstream from the break. By using the limited sources of gas in the Eureka area (propane-air and local natural-gas sources), and by curtailing interruptible customers, the company would have approximately 24 hr to repair the break before running out of gas in Eureka. In the meantime, it would take 8–12 hr to repressure the main east of the break. Until the main could be isolated on the upstream side of the break, many thousands of dollars worth of gas would disappear into the atmosphere. This also could rob the rest of the system of much-needed gas.

Rupture Control Equipment

An experienced pressure operator at the Eureka load center might detect a break by observing the telemetered information available to him, but isolation and location of the break might take hours if it became necessary to dispatch men to patrol the pipeline. Previously, the company faced a similar problem on its Topock-Milpitas pipeline,[1] and installed line rupture controls. On the basis of experience with these controls, the company decided to use the same basic system on the Eureka pipeline. It equipped five locations with line rupture control equipment interspersed with check valves to provide some additional protection.

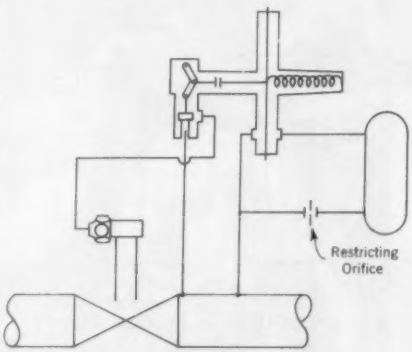

Fig. 2. One Type of Line Rupture Sensing Device

A rapid pressure change in the line is sensed when a pressure difference occurs between the line and the capacity tank.

The automatic equipment for line rupture control senses a major line break, initiates valve closures to isolate the ruptured section, and reports the

location of the trouble to the nearest attended station.

There are two methods currently used in the gas industry to sense a line rupture. One method, the rate of pressure change, uses a capacity tank and a small restricting orifice (Fig. 2). A line rupture resulting in rapid fall in pressure in the line causes a pressure difference between the line and the capacity tank. A sensing device between the line and the tank detects this change and initiates a valve closure. The second method uses a

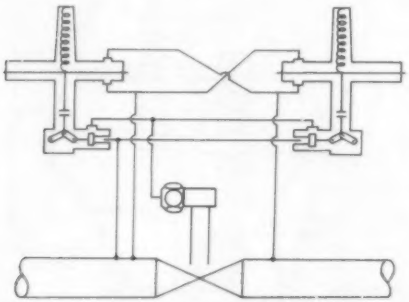

Fig. 3. Method of Rupture Sensing Selected

With a plug-type line valve, either an abnormal or reverse flow is detected and valve closure is initiated.

plug-type line valve as a differential metering device (Fig. 3). A differential sensing device detects either an abnormal or reverse flow and initiates a valve closure.

There was some concern that the first method, the rate of pressure change, might close more valves in the system than would be necessary. Also, there was the possibility that the restricting orifice in this system could become blocked, which would cause an inadvertent valve closure with normal variations in line pressure. The second method, therefore, was employed on the Corning-Eureka line, as it had been on the Topock-Milpitas line.

The heart of the control system is the differential trip valve, which is merely a spring-loaded diaphragm device (Fig. 4). The high pressure opposes the spring and the low pressure is applied to the opposite side of the diaphragm. If the differential pressure overcomes the spring, a valve that permits the operating medium to act on a motor or piston is tripped. After the valve is tripped, it remains open until manually reset, even though the measured differential may fall to a normal level.

In this application, line gas at reduced pressure is used as the operating medium; this gas operates a rotary diaphragm piston motor which, in turn, closes the valve (Fig. 5).

The trip valves, their associated equipment, and a differential pressure recorder, diagramed in Fig. 6, are mounted on a pipe stand in a demountable shelter for protection from the winter rains and snows (Fig. 7). These shelters are mounted about 2 ft high on pipe legs to permit snow to blow under the shelter rather than to drift over it. A second identical shelter is provided nearby for the alarm equipment (Fig. 8). A pressure switch that will sense the operation of either of the trip valves is provided. This pressure switch is used to initiate the alarm equipment.

It might be of interest that this control system could be adapted to water service merely by plating a few internal parts of the trip valves and regulators. The motors were actually designed for hydraulic service. The manufacturer of the trip valves, however, has had little experience with water problems, and he cautions:

"We believe the only way the suitability of this valve for use with water could be established would be on an experimental basis in a typical field application where all effects of this service would come into play."

Problem of Location

The problem of line rupture control is threefold—detection, isolation, and location. The problems of detection and isolation can be met with the purely mechanical equipment described above. The problem of location would be reduced immeasurably if it were possible to indicate immediately to an attended location which valves had operated in the event of a line break. This could be done with an annunciator-type alarm system.

The ideal alarm system is one that continually monitors itself. This is particularly true when the alarm is to indicate the operation of a passive device, such as the line rupture controls. In the absence of a continuous self-monitoring feature, an alarm system should occasionally exercise itself or at the very least be capable of demand interrogation.

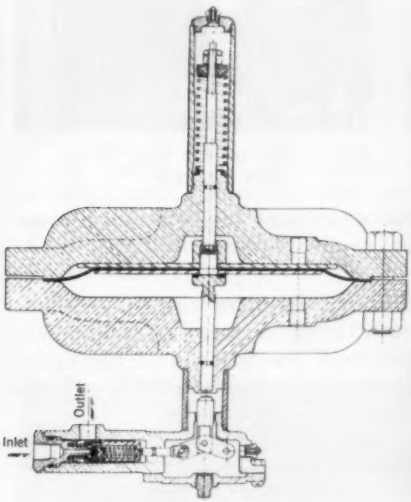

Fig. 4. Differential Trip Valve

If pressure difference is great enough to overcome the spring, a valve is opened to allow the gas to operate a diaphragm piston motor.

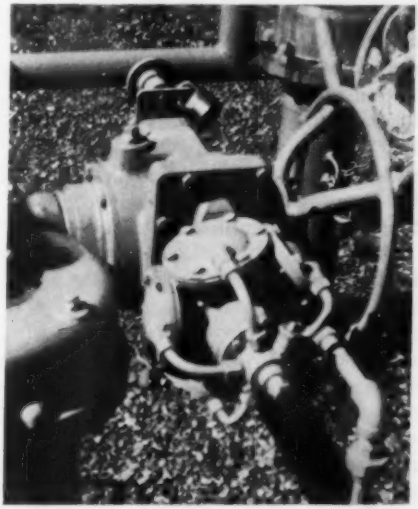

Fig. 5. Motor and Gear Reducer Mounted on Valve

Piston motor, operated by gas pressure, can close valve. Valve may be operated with hand wheel (right of valve).

The wilderness area through which the Corning-Eureka pipeline was built precluded the use of conventional telemetering techniques permitting the inclusion of any of the above features. With only one exception, the line rupture valves are located at a considerable distance from commercial telephone and power lines. Some thought was given to the use of power line

carrier, using the company's 110,000-v transmission line, which roughly parallels the gas line. The problems that the necessary protective structures, traps, and filters would pose, however, reduced the use of power line carriers to a last resort.

Mobile Radio System

The only feasible means of communication in the area was the company's mobile radio system. Through a system of mountain top repeater stations controlled from the Cottonwood substation and the Humboldt load center, there is almost blanket coverage of the area. One possibility for an alarm system was to use the mobile system for transmitting a distinctive signal that could be identified by the operator.

As early as 1956, FCC had authorized the use of "tone signals for control purposes other than the establishment or maintenance of voice communications" for licensees of the Forest Products Radio Services [2] and the Railroad Radio Service.[3]

Subsequently the National Committee for Utilities Radio urged the commission to extend this privilege to the Power Radio Service to permit the use of tone signaling and outage indicators.[4] FCC amended its ruling to permit "a mobile service licensee in the Power Radio Service . . . to operate an Operations Fixed Station on any mobile frequency . . . for the sole purpose of automatically indicating failures in electric power transmission systems." [5]

On the basis of this favorable ruling, the National Committee for Utilities Radio and the American Gas Association filed petitions for reconsideration of this ruling seeking "to afford the same privileges to gas, water, and steam licensees to locate failures in

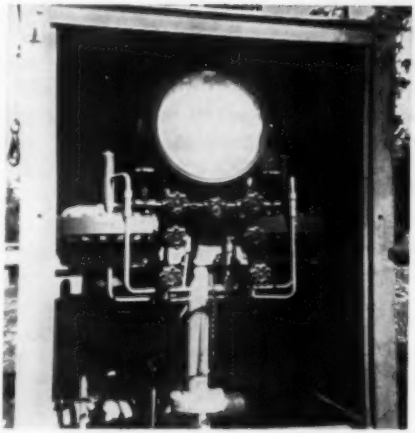

Fig. 7. Shelter for Trip Valves and Recorder

Shelter protects equipment from mountain weather.

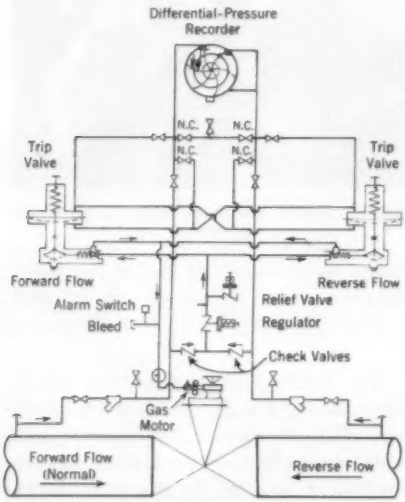

Fig. 6. Trip Valves and Assorted Equipment

Equipment senses abnormal or reverse flow, closes valve, initiates alarm, and records pressure differential.

their transmission and distribution systems." These petitions were again followed by favorable action by FCC (see Appendix).

On the basis of this new ruling and the almost immediate approval of its license application, the author's company placed orders for the remote outage indicators and the base station equipment. At that time there was only one type of outage locator commercially available. The remote unit of the available equipment met the system requirements in many respects, but the decoding equipment at the base station did not meet the requirements established for this service.

The remote alarm unit consists of a mobile radio transmitter that emits a pulsed audio tone of not more than 3-sec duration once each minute for 5 min.

The decoding equipment offered at that time consisted of a tone-sensitive device that monitors the mobile base station communication receiver. This equipment records pips on a heat-sensitive recording tape. The tape remains stationary in the recorder until a tone of the correct frequency is received.

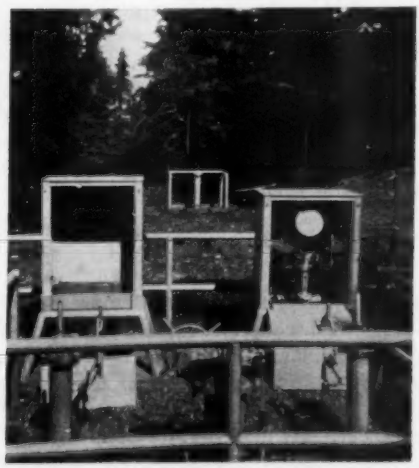

Fig. 8. Alarm Equipment Shelter Beside Trip Valve Shelter

Alarm equipment is also placed in a protective shelter.

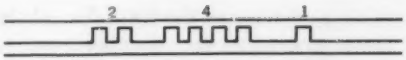

Fig. 9. Code Display for Unit 241 on Heat-Sensitive Tape

Pips are recorded as pulsed tones and received from remote units.

When a tone is received, the recorder is started and the pips are recorded. At the same time, an audible alarm is sounded. The tape is then visually scanned to determine which indicator has alarmed (see Fig. 9).

Concern arose that the heated writing head of the recorder, which stays for long periods on a single point of the tape, could conceivably cause a tape failure and a subsequent loss of record. Because of the operator's inability to interrogate the status of alarms, a tape failure would mean that the alarm information would be irretrievably lost.

It was the company's opinion that a conventional electromechanical relay pulse-counting system with a visual annunciator display would have a better chance of getting at least one valid registration out of the five code transmission than the tape-type monitor would.

Operation of Equipment

The line rupture valves are located in two operating divisions, Shasta and Humboldt, each having its own mobile radio frequency. A field survey was made, including signal strength measurements at each of the repeater sta-

tions, to determine the feasibility of the alarm system at each location, and to determine on which frequency each unit should transmit. It was found through this survey that three of the locations should be monitored from the Cottonwood substation in the Shasta division and the other two from the Humboldt Load center in Eureka (Fig. 1).

The remote units consist of a standard 12-v mobile transmitter, a timer, a single-tone oscillator, and a motor code sender. The action of a differential trip valve closes the pressure switch that starts the timer. The timer, in turn, immediately energizes the transmitter and tone oscillator filaments and the transmitter crystal oven. Approximately 1 min later, after the crystal has reached stabilization temperature, the timer initiates the code transmission sequence.

During the code transmission sequence, the transmitter is turned on for 3 sec, during which time a unit-identifying two-digit decimal code is transmitted with a specific tone at approximately 10 cycles per second. The transmission is repeated five times at 1-min intervals, after which the unit shuts down.

This unit, along with the necessary batteries, will be mounted in the second shelter. A yagi antenna (a radiating antenna and one or more directors and reflectors arranged along a line) will be mounted on an adjacent 60-ft pole. Presently it is planned that dry cells will be used for battery power. As the alarm system is completely passive, with the exception of an occasional manual test sequence, shelf life will govern the frequency of battery replacement. Dry cells have a better low-temperature characteristic

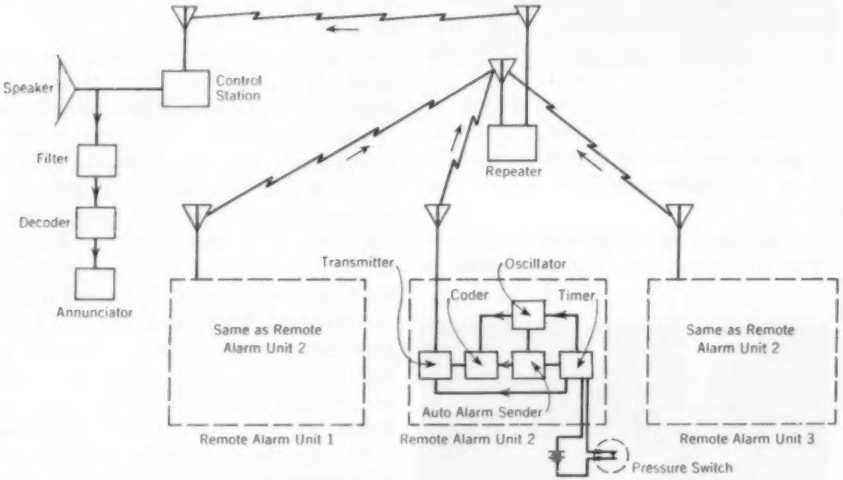

Fig. 10. Operation of Alarm System

Signals from all remote alarm units are received by control station through repeater.

than do most wet cells or storage batteries.

Figure 10 diagrams the alarm system. The base station monitoring equipment consists of a band pass filter, an amplifier, a digital decoder, an alarm bell, and an annunciator for visual display. The band pass filter is connected in parallel with the speaker of the communications receiver. If a tone of the proper frequency is detected, it is amplified and initiates an audible alarm and operates the digital decoder. If the pulse count is valid, that is, if it matches the code of one of the remote units, the appropriate annunciator light is lighted. If the code is incorrect, it is rejected, but the audible alarm is still sounded.

The decoding equipment at Cottonwood substation is incorporated in a single chassis which will be mounted on a standard 19-in. rack (Fig. 11). The communication racks at Cottonwood are all within sight of the operator, and no problem is posed by having the annunciator indication at this point.

At the Humboldt load center, the communication racks are located in another room. In this case, the annunciator and alarm bell will be installed in a separate assembly.

System Limitations

This system is limited in its operation by the present rules of FCC in that it is impossible to verify an alarm or check the status of the various remote units after a false or unintelligible alarm. Serious consideration has been given to the possibility of adding an interrogation feature. If FCC should permit two-way signaling, it would be entirely feasible to add a remote receiver and some associated decoding equipment at the remote locations. Reasonable battery life could be achieved by disconnecting the speaker of a transistorized receiver. Leaving the speaker connected would result in increased battery drain during periods of normal voice traffic on the mobile system.

In regard to this possibility, FCC has had some correspondence with the National Committee for Utilities Radio regarding proposed rule changes regulating the use of coded tones for purposes other than indication of actual failure or outage. These would include request telemetering or status indication, remote operation of various devices, abnormal or automatic operation indication, and many others.

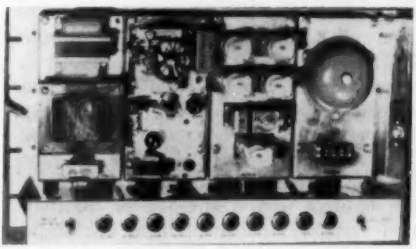

Fig. 11. Decoding Equipment Mounted on Single Chassis

Alarm bell rings and appropriate alarm light goes on to indicate a valve closure.

The decision to use a one-way alarm system was based almost entirely on the lack of other means of communication. Such an alarm system falls short of the normal requirements of reliability. When FCC permits the use of two-way signaling, the company's present equipment will become a valuable adjunct to the other conventional communication links for alarms, telemeters, and supervisory controls.

References

1. STANNARD, J. H., JR., & MORCOTT, TOD. A Monitoring System for the Line Rupture Control of the PG&E "Super Inch" Pipeline. *Pipeline Ind.*, 6:8:22 (1958).
2. FCC Public Notice 38582 (Nov. 15, 1956).
3. FCC Public Notice 39623 (Dec. 13, 1956).
4. FCC Docket 12028, Responses of the National Committee for Utilities Radio (Jun. 17, 1957).
5. FCC-57-823 Report & Order (Jul. 25, 1957).

Appendix

Copy FCC Docket No. 12028, Appendix Released Jun. 4, 1959

Paragraph (d) of Section 11.253 is amended to read as follows:

11.253 Frequencies available for operational fixed stations.

(d) A mobile service licensee in the Power Radio Service may be authorized to operate an Operational Fixed Station on any mobile service frequency above 25 megacycles already assigned to the licensee, where such fixed operation is for the sole purpose of automatically indicating failures in transmission or distribution systems. All such fixed operations are subject to the condition that no harmful interference be caused to any station in the mobile service operating on the same frequency, and are further subject to the following limitations, requirements and exemptions:

1. The plate power input to the final radio frequency stage of any transmitter shall not exceed 50 w.

2. Without the necessity of the showing specified by Section 11.103(b), and notwithstanding the other provisions of Section 11.103, authorizations will be issued for types A1, A2, or F2 emission with a maximum authorized bandwidth not to exceed that permissible for mobile service use of the frequency involved.

3. With respect to a particular failure an Operational Fixed Station licensed pursuant to this paragraph is limited to a total of five transmissions of up to three seconds each, no two transmissions to commence in the same 60-sec period.

4. No transmitter shall transmit its call letters or geographical location except by means of special code.

5. All Operational Fixed Stations licensed pursuant to this paragraph are exempt from the requirements of Section 11.54(e)(2), 11.107(c), 11.152 and 11.154: *Provided, however,* that all transmitter adjustments or tests having potential effect upon the proper operation of such Stations shall be made by or under the immediate supervision and responsibility of a person holding a first or second class commercial radio operator license, either radiotelephone or radiotelegraph.

Lagoon Disposal of Lime Sludge

Louis R. Howson

A paper presented on Mar. 21, 1960, at the Illinois Section Meeting, Chicago, Ill., by Louis R. Howson, Partner, Alvord, Burdick & Howson, Chicago, Ill.

THE disposal of sludge from lime water-softening plants has been a major operating problem since municipal lime water softening in the United States was begun at Oberlin, Ohio, nearly 60 years ago. The reason for this problem is largely one of economics. Situations in which the sludge can economically be reclaimed and recalcined are relatively few. Probably more than 90 per cent of the lime-soda softening plants in this country find the disposal of lime sludge on the red side of the ledger. Thus they try to get rid of the sludge in the cheapest way possible—usually by lagooning or discharging it into streams.

This situation is not limited to water softening plants. In many sewage treatment plants, the disposal of sewage sludge has also become a more difficult problem than the sewage treatment itself. Although lime sludge disposal by lagooning has been practiced more extensively than all other methods of disposal for several decades, there are few data and little in the literature to assist in avoiding the annoyances commonly arising from this method of disposal. This discussion is an evaluation of some of the variables, made so that some of the difficulties might be avoided.

Sludge Disposal in Illinois

Some years ago an AWWA committee studied and reported on the disposal of wastes from water purification and softening plants. The committee made an inventory of the procedures for disposing of softening plant sludge used in 1944. The census made in that study [1] showed that 58.4 per cent of the plants reported disposed of their sludge in water courses, 29.6 per cent in sludge beds or lagoons, and 8.6 per cent to sewers, leaving only 3.4 per cent disposed of by other methods. Dilution and lagooning was the method of 88 per cent of all plants then in operation.

Illinois, with 41 softening plants at that time (11 per cent of those reporting), had 66 per cent of those plants using sludge beds or lagoons, 12 per cent discharging to flowing water courses, and 17 per cent to sewers. The high percentage of Illinois plants discharging to sewers is probably a reflection of the number of suburban villages in the Chicago area that discharge their sludge to sewers leading to the large treatment plants of the Metropolitan Sanitary District. These softening plant wastes constitute a small part of the total sewage flow treated in the Metropolitan Sanitary District plants. This practice has been followed for many years without apparent detriment to the sewage treatment process. In fact, the sludges have sometimes been reported as assisting in the precipitation of the sewage solids.

At one Chicago suburb, just outside the Metropolitan Sanitary District and having its own sewage treatment plant, the softening plant sludge was discharged to the sewers for several years. The sludge finally accumulated in the hoppers of the Imhoff tanks to such an extent that it seriously affected the efficiency of the plant and its capacity to handle sewage wastes. When this was discovered, the softening sludge was diverted from the sewers and pumped to two lagoons, which were used for some 6–8 years.

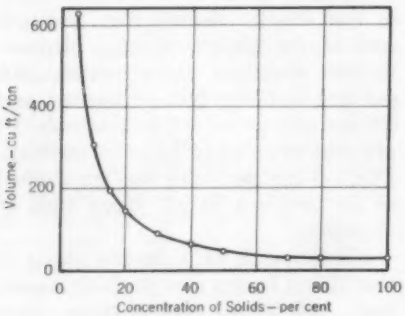

Fig. 1. Lime Sludge Volume and Solids Concentration

Good handling practices at the lagoon can increase solids concentration, thus increasing storage capacity.

Later, since residential development approached the lagoon area, the softening sludge has been hauled by truck to a large, abandoned gravel pit near the sewage treatment plant, at a cost of $12,000 per year. Figures presented below indicate that approximately 75 per cent of the $12,000 now expended for hauling the liquid by truck could be saved by investing approximately $50,000 in a 3-mi pipeline.

There are wide variations in the character and density of sludges as well as marked differences in the ways they are handled in lagoons.

Volume of Sludge

By and large, each pound of commercial quicklime used in the softening process results in about 2.5 lb of dry softening sludge. As the sludge comes from the basins, it may contain about 1–10 per cent solids, with the volumes of sludge to be handled varying inversely to the concentration of solids (Fig. 1).

Thus the percentage of solids in the sludge as it comes from the settling basins obviously affects the storage capacity that must be provided in lagoons, but that capacity is also affected by whether continuous rather than rotating use, withdrawal of supernatant water, and exposure of the sludge to air drying are practiced.

In one Illinois plant, for example, the sludge is discharged into an abandoned quarry covering 6–7 acres, and originally 60 ft deep. The sludge has been deposited in water. As a result, the sludge is of low solids concentration, and the storage volume is reported to be about 75 per cent occupied in less than 20 years. Unless the water is removed from the quarry to provide added space for sludge and to facilitate its compaction and drying, additional storage volume will be needed in a few years.

When deposited under water, sludge remains flocculant. Where the capacity of the sludge storage basin is limited, the supernatant should be withdrawn and disposed of.

There is abundant experience to demonstrate that most softening-plant sludge can be dried in lagoons or on beds to approximately 50 per cent moisture content, about the same as ordinary soils. When dried to 50 per

cent solids or even a little higher water content, the sludge can readily be handled by drag line equipment and removed from beds or lagoons, if desired.

Considerable experience has been accumulated as to the volume that must be provided for sludge disposal. In order to make data from several softening plants readily usable, they have been expressed in acre-feet per year of 50 per cent moisture sludge per million gallons per day of water softened per 100 ppm of hardness removed. Table 1 shows the figures for a few plants where adequate data are available.

TABLE 1

Amount of Sludge Produced by Lime Hardness Removal

City	Acre-ft of 50% Sludge/yr/mgd/ 100 ppm Hardness Removed
Cedar Rapids, Iowa	0.62
Columbus, Ohio	0.52
Sandusky, Ohio	0.66
Lansing, Mich.	0.65
Hinsdale, Ill.	0.45

It will be noted from these figures that the capacity required on the assumption that the sludge is drained to 50 per cent moisture varies from 0.45 to 0.66 acre-ft/yr/mgd/100 ppm of hardness removal. Some of these records are for fairly long periods; for instance, the Lansing, Mich., records cover a period of 15 years, during which the softening plant sludge was stored in three lagoons used alternately so as to attain maximum concentration of solids. During this 15-year period, the water consumption averaged approximately 14 mgd; the average hardness removed was 289 ppm. These lagoons were each 5.75 acres in area, and in 15 years accumulated a depth of 17 ft.

In contrast to the figures in Table 1, Thomas R. Lathrop has called attention to sludge lagooning at Marion, Ohio, where a lagoon with three times as much storage volume as that at the five plants in Table 1 was completely filled in 1 year.[3] It is reported that this lagoon, an abandoned quarry and borrow pit 400 ft long, 75 ft wide, and 20 ft deep, was filled with sludge in about a year. The moisture content of the pit was not reported, but it is stated that "after drying for some time, the moisture content is reduced to about 60 per cent. It is difficult to get a lower moisture content, and the sludge is of such consistency that it is difficult to handle."

The Marion situation, as compared to that at Lansing, illustrates another important factor in lagooning lime sludges—good practices in the use of storage volume. There should be a sufficient number of basins, usually not less than three, so that one basin can be filled to a depth of some 3–5 ft with sludge as it is drawn from the tanks. Sludge should be stored long enough for its moisture to be reduced to 50 per cent before additional sludge is added. By that time, the sludge will have shrunk to about 16 per cent of its volume as discharged to the lagoon. That is, a 36-in. loading would probably shrink to less than 6 in. When that is accomplished, the lagoon can again be filled and the process repeated. Filling a deep lagoon (20 ft at Marion) without decanting the supernatant so as to expose the sludge surface to air drying and without providing opportunity for the sludge to dry itself before new wet sludge is added is wasteful of sludge storage space. Computations would indicate that the Marion quarry sludge probably had an average moisture content

of about 80 per cent when it became full at the end of the year's use.

Because of the desirability of filling the same lagoon several times, berms should originally be made at least 6–8 ft high. The berms should also be of such width, about 12 ft, that a drag line can operate from them to pull dried sludge up out of the lagoons to increase the berm height and to increase the overall storage capacity. Sludge so removed with about 50 per cent moisture may be "gummy" when placed on top of the berms, but will readily dry out and form excellent impervious embankment material.

It is also good practice to fill lagoons at one end and drain off the supernatant at the other end. That will cause the sludge to flow over the entire lagoon area. The supernatant should be kept drained off so as to expose the sludge to the air to facilitate drying.

Transportation of Sludge

Hydraulic transportation is the cheapest way to move liquid sludge from the treatment plant to the disposal site. The quantities are small, and a 6-in. pipeline will usually be adequate to transport the sludge from a city of nearly 500,000 people. The sludge in ordinary consistency pumps readily, and few problems have been experienced with transporting distances of 2 or more miles. Asbestos-cement pipe is frequently used for that purpose. In most areas, which are usually semirural around the lagoons, the cost will approximate $18,000 per mile for 6-in. pipe. For a city of 100,000 or less, 4-in. pipe will usually be adequate.

Estimates have been made of the cost of pumping lime sludge to disposal sites with land costing $150–$450 per acre and with distances of 1–3 mi. The estimates are based on purchasing 3.3 acres of land per mgd of treatment plant capacity, which should be adequate when developed by multiple basins operated on a "fill and dry" basis and where the hardness removed is 200 ppm or less. In locations where the hardness removal exceeds 200 ppm, larger area or deeper lagoons should be provided. Where lower land costs are available farther from the plant, longer pipe lines may be justified.

Based on a 10-mgd softening plant, the annual costs will vary from approximately $125 to $250/mgd/100 ppm of hardness removed. In other words, lagooning the sludge from a plant handling 10 mgd from which 100 ppm of hardness is removed will cost $1,250–$2,500 per year, including the cost of pumping the sludge and the interest and amortization of the cost when financing with 4 per cent 30-year revenue bonds.

Conclusions

From the foregoing general observations it is believed that the following conclusions may be drawn.

1. Where land is available for sludge disposal by lagooning, that method is usually most economical.

2. The cheapest means of transporting sludge from the treatment plant to the disposal plant site is by pumping through a pipeline.

3. Although sludges vary in their character, composition, and volume, it may be assumed without material error that on a dry basis there will be approximately 2.5 lb of sludge produced per pound of commercial lime used in the softening process.

4. Most softening plant sludges will air-dry in well designed lagoons or

beds and operated with supernatant removed to facilitate drying to about 50 per cent moisture.

5. When lime-softening sludge is reduced to 50 per cent moisture content, it will occupy only 16 per cent as much space as when applied containing 90 per cent moisture, or 8 per cent as much volume as when applied with 95 per cent moisture.

6. Although data upon which to base an opinion are meager, it is believed that sludge deposited in a lagoon where it is always submerged will not compact to less than about 70 per cent water. In this condition it will occupy twice as much storage space as it would if dried to 50 per cent.

7. About 0.5–1 acre-ft/yr/mgd/100 ppm of hardness removed is required to store sludge for one year when dried to 50 per cent moisture.

8. Where lagooning is practiced, there should be at least three lagoons, each capable of holding approximately one year's supply of wet sludge.

9. As a general figure where sludge can be lagooned to 10 ft deep, it is desirable to have 3–5 acres available for sludge beds for each mgd plant capacity in order to provide for the future.

10. Beds, besides being in multiple and with supernatant regularly drained, should be operated on a "fill and let dry" basis. Sludge should be applied to a depth of 3–5 ft which, when dried to 50 per cent moisture, will usually shrink to 6–10 in. deep.

11. Because of the desirability of applying at least 3 ft at a time, berms surrounding sludge lagoons should be built 3–5 ft above maximum sludge level when filled. Berms should be broad enough (about 12 ft) to permit operating a drag line on them and to permit raising their top elevation.

12. Sludge dried to about 50 per cent moisture makes excellent material for berms and will further dry out and compact to make an impervious fill when placed on top of berms.

13. In operating lagoons for sludge beds, it is desirable to fill at one end and decant or otherwise withdraw supernatant at the other end.

14. It is desirable to keep the water level in lagoons as low as possible to facilitate compaction. Experience has demonstrated that 50 per cent solids is practicable.

References

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2. Lathrop, T. R. Disposal of Sludge at Water Purification and Softening Works of the Mahoning Valley Sanitary District—Discussion. *Jour. AWWA*, 24:1531 (Nov. 1933).

Pipe System

AWWA Distribution Manual

A training course in water distribution has been prepared under the supervision of AWWA Committee 4620 M—Education. The document is being published in installments (April 1961 issue, p. 458; June 1961 issue, p. 790; July 1961 issue, p. 907), and will afterwards be made available as a separate volume.

MANY construction materials have been used to carry water, first with gravity flow and later with flow under pressure. Stone, vitrified clay, wood, lead, copper, cast iron, wrought iron, steel, cement, concrete—even bamboo—and various combinations of materials have all been used. It is worthwhile to have some knowledge of the older pipe materials, because some of these presently little used materials are still in service in many of the older water systems.

Modern types of pipe commonly used for carrying water under pressure include cast iron, asbestos-cement, steel, and plain and prestressed reinforced concrete, with or without an internal steel cylinder. In the smaller sizes of distribution piping, steel, wrought iron, cast iron, copper, brass, lead, and even synthetic materials are in common use. Plastic pipe, a relative newcomer in the field, is being actively developed, tested, and installed in sizes ranging up to 12 in. in diameter.

There still remain in service, particularly in the northeastern United States, many pipelines of cement-lined and coated sheet iron installed during the middle of the nineteenth century. In many sections of the country wood stave and riveted or lock-bar steel pipelines laid early in this century are continuing to serve as water carriers.

Cast-Iron Pipe

The first recorded use of cast-iron pipe was in Germany in 1455. In the fountains at Versailles, France, cast-iron mains laid in 1664 are still in service. The earliest recorded use of cast-iron pipe in water distribution systems in the United States was in Philadelphia in 1817. The material is highly resistant to corrosion and has other desirable properties. With the exception of pipe laid in corrosive locations, few cast-iron pipelines have deteriorated sufficiently in physical condition to establish a measure of their ultimate life.

There have been four chief types of cast-iron pipe differentiated by method of manufacture: (1) horizontally cast; (2) pit cast (vertically cast in sand molds); (3) centrifugally cast in sand-lined molds; and (4) centrifugally cast in metal molds. Only the last two types of cast-iron pipe are in general production today.

Cast-iron pipe was originally used without special coating or lining. Later the cast pipe was dipped into a vat to coat and line it with a coal-tar pitch varnish or enamel. Such linings did not protect the interior surface for long from the action of certain waters, and subsequent pitting and the formation of growths known as tubercles substantially increased friction and reduced carrying capacity. A method of lining with cement mortar was introduced about 1920. This lining, together with thicker, centrifugally applied bituminous linings, protects the interior of the pipe from tuberculation and preserves its carrying capacity. Except in certain locations or under special conditions, most cast-iron pipe now being installed is lined with cement mortar or bituminous enamel. Friction losses in older unlined pipe may be, and frequently are, more than twice as much as in lined pipe.

Asbestos-Cement Pipe

Asbestos-cement pipe, in use for over 30 years, is composed of asbestos fiber and portland cement mortar combined under pressure into a homogeneous structure in which a strong bond is effected between the two materials. Among its advantages are a high resistance to most corrosive conditions; freedom from electrolysis; its ease of handling, installation, jointing, and tapping; flexible joints; and a high sustained carrying capacity under most conditions. Some disadvantages are its relatively low resistance to flexural stresses, causing breakage and necessitating care in bedding and installation; its susceptibility to puncture by rocks or tools; and its nonconductivity, which makes electric thawing impossible.

Steel Pipe

Steel pipe has long been used for water distribution. The development of welding techniques has increased the use of steel pipe, particularly in the larger sizes. It is lighter in weight than cast-iron or concrete and is easily cut and welded. It is easily installed and jointed, has some flexibility in action, and can be designed in thickness and strength to meet the most severe conditions. It is, however, less durable and sometimes more expensive than competitive pipe, although protective linings and coatings can be applied to increase its durability and service life. Such linings are, however, sometimes adversely affected by the flexibility of the pipe if subjected to bending from trench loads.

Reinforced-Concrete Pipe

Reinforced-concrete pipe has long been used for the larger sizes of transmsision and distribution mains. Since the advent of prestressed-concrete pipe in the early 1940's, more and more of this type of pipe has been used in sizes 16 in. and larger. It is generally more economical in these sizes than other types of pipe. It has the advantages of durability, strength, flexible joints, sustained carrying capacity, and ease of installation. Although it is heavy and somewhat difficult and costly to tap, its many advantageous features have rapidly brought modern prestressed-concrete pipe to the fore among the kinds of pipe used in larger sizes for distribution systems.

Plastic Pipe

The introduction of plastics as pipe materials in the past few years has raised increasing interest in this material for water system use. In small sizes, it is being used more and more—for instance, in service lines. It is light in weight, generally noncorrosive, and has a high carrying capacity. The jointing problem is being satisfactorily solved. The installation of plastic pipe may, in time, take the form of a more or less continuous extrusion process. Undoubtedly plastic pipe will become more and more used as refinements in materials, manufacture, and installation progress.

Fittings

The basic materials for special fittings required in the pipe system, such as tees, crosses, and bends, are cast iron and steel. The use of cast-iron fittings with cast-iron and asbestos-cement pipe is considered standard. These fittings can also be used with concrete and steel pipe with suitable adapters. Asbestos-cement pipe also requires adapters for 8-in. and larger sizes. Made-up concrete and steel fittings are also provided by the manufacturers of those types of pipe.

Jointing Materials and Methods

Until about 1935 the common type of joint for cast-iron pipe was the bell-and-spigot joint. After assembling the pipe by inserting the spigot into the bell end, the joint was made tight by packing strands of jute or yarn in the joint and then pouring a molten material, calking it after hardening to seal the joint. At first lead was commonly used for this purpose. About 1920 various sulfur compound materials were substituted for the lead and came into common use. In some parts of the country cement joints made of neat cement slightly moistened and calked were quite commonly used.

The next development was a bolted type of mechanical joint consisting of a follower ring pulled up by bolts to compress a rubber gasket. This

joint largely displaced the poured joint. It provided watertightness under pressure as well as joint flexibility.

Since 1955 rubber-gasketed bell-and-spigot slip joints have largely superceded all other types of joints for use with cast-iron pipe. These are provided by various manufacturers under trade names, all essentially consisting of a rubber or composition gasket fitted and held in the bell end of the joint, the spigot end being shoved into the bell, compressing the gasket. Watertightness, flexibility, and ease and economy of installation are all features of this type of joint.

Asbestos-cement pipe is joined with a roll-on rubber gasket coupling made of similar material. Steel pipe may be welded or have plain ends joined with mechanical rubber-gasketed couplings. Concrete pipe uses slip-on rubber-gasketed bell-and-spigot joints similar to those now used with cast-iron pipe.

Valves and Hydrants

The selection and location of valves and hydrants are of great importance to a properly designed distribution system. As valves form a part of the pipe system and remain in service for many years, care should be exercised in selecting them for steady and long-lasting service.

Valves

The standard valve for distribution service has in the past been the double-disc parallel-seat cast-iron valve with bronze-mounted seat and gate rings, wedges, and a non-rising stem. Normally, valves are placed in the pipeline with a valve box extending to the street surface. They have a nut at the top over which is fitted a gate key for opening and closing the valve. Frequently larger valves are placed in vaults, with manhole access, to facilitate operation and maintenance. Large valves generally are equipped with small bypass valves to reduce pressure differentials upon opening and closing and often have spur or bevel gearing to reduce the labor of operation. If valves are laid horizontally in the pipeline, care should be taken to have the valves equipped with bronze or babbitt tracks to carry the weight of the gates throughout their travel on rollers or shoes.

Double-disc valves with inclined seats and solid-wedge type valves are also used in distribution pipelines.

Recently, and more commonly in the larger sizes, rubber-seated butterfly valves are being increasingly used in distribution installations.

Hydrants

Fire hydrants for ordinary water service are usually one of two types of post hydrants—the compression type (opening against or with the pressure) and the gate type. They may have from one to four nozzles, the most common being equipped with two $2\frac{1}{2}$-in. hose nozzles and one 4-in. steamer or pumper nozzle.

The size of hydrant refers to the size of the hydrant main valve opening, which may vary from 4 to 6 in. in diameter. For two hose nozzles and one steamer nozzle a hydrant usually should have at least a 5-in. valve opening. The length of a hydrant, or "bury," is the distance from the bottom of the connecting pipe to the ground line at the hydrant and is generally given in units of $\frac{1}{2}$ ft.

Hydrant barrels are of cast iron with moving parts, such as valve facing, being of bronze or other noncorrodible metal. The barrel and operating mechanism should be so designed that, in the event of damage or breaking of the hydrant above or near the grade level, the main valve will remain reasonably tight against leaking or flooding.

Design Requirements

Pipe and special fittings used in distribution systems must be designed to withstand the various forces acting upon them. They must withstand internal water pressure induced by static and kinetic pressures and such shock pressures as result from water hammer. They must withstand external pressures acting on them such as from trench loads and live loads resulting from heavy traffic and impact.

Pipe is generally purchased for several standard ratings. In common practice, pipe is designed for four classes of working pressures 100 psi, 150 psi, 200 psi, and 250 psi. Pipe is tested to several times the normal working pressures, and allowances are made for water hammer.

Exterior trench and traffic loadings must similarly be provided for as to the shape, width, and depth of the trench, as well as methods of backfilling. All these factors play a part in how much exterior pressures are exerted on the pipe. Design tables for determining the thickness of metal required in various sizes of pit-cast and centrifugally cast pipe under varying internal pressures, trench conditions, and depths of cover have been promulgated as part of AWWA C101.*

Standards

"Standards" are documents setting forth generally recognized measures or requirements for materials or services as established by competent authority after experimentation, test, and experience in actual practice. They are commonly used as an aid to the purchaser of products or services in the writing of his own contract specifications. Although a standard may not have any legal force of its own, compliance with all or certain of its provisions may be required by the purchaser as part of his contract agreement with the purveyor of products or services. Thus, as standards come

* American Standard Practice Manual for the Computation of Strength and Thickness of Cast-Iron Pipe—AWWA C101 (ASA A21.1). Am. Wtr. Wks. Assn., New York (1957).

into greater and greater use, the purveyor is persuaded to improve his product or service to comply with generally accepted measures of quality, and the interests of both purchaser and purveyor are better served.

In the water supply field, the principal organizations producing recognized standards are AWWA, ASA, ASTM, and the federal government, although many other organizations produce standards that are of some interest to the field.

Selection of Materials

A number of factors must be weighed in selecting the best type of pipe for installation in any system or even in different parts of the system. Relative costs, availability, durability, initial and sustained carrying capacity, and ease and economy of installation and maintenance should all be considered.

Of the pipe materials presently being used, cast iron and prestressed concrete are the most rugged and durable. In streets with heavy traffic and good pavement the most durable materials should be used to insure long life and low maintenance costs. On less important streets and private rights-of-way, durability is not so important if economies can otherwise be effected. All pipeline installations should be designed for the maximum pressures they are likely to undergo as well as for the particular trench loadings expected.

Special installations, such as subaqueous stream crossings, installations on bridges, or important highway or railroad crossings, may require special treatment.

Ease of Installation and Repair

In addition to the cost of the materials, the expense of installation is important. Pipe manufacturers, over the years, by continued research, have developed new methods of joining pipe to save labor costs.

The progress made in methods of joining pipe has produced joints that are about as economical and easy to make as appears possible. Contractors are sometimes slow to accept new methods of installation and to pass along the resulting reduction in costs. In time, competition forces them to do so.

In simplifying their products, pipe manufacturers have reduced the length of shutdown time and labor needed to make repairs. A certain amount of repair and maintenance work is unavoidable, and a stock of repair items must be maintained. Overstocking of repair items should be avoided, but a sufficient supply of items should always be kept on hand for routine repairs.

Not only are stock repair items important, but an experienced supervisor on the job can contribute immeasurably to the efficiency of the work and reduce the length of service interruptions.

Location of Facilities

New mains are installed for four basic reasons: (1) extension of service to new customers; (2) general reinforcement; (3) localized reinforcement; and (4) replacement of existing facilities. A study should be made in each case to select the pipe sizes and locations adequately to satisfy present and future demands.

Each installation should be studied to determine the best location for the proposed pipeline. Certain locations, such as south and east sides of streets, may be ordered by the municipality, or may be mutually agreed on by the various utilities using the streets.

Some consistent pattern for locating pipelines, valves, and hydrants should be developed and closely followed. There may be preferred locations within the street limits which could reduce installation costs. Pavement removal and replacement are so expensive that if pipes can be located in control turf areas or even under sidewalks costs can be reduced. Location of other utility lines, such as gas, telephone, sewer, and heating conduits, sometimes makes proper location of the water lines difficult.

In some locations a dual or two-main system may be advisable, with a large main for fire protection on one side of the street and a smaller service main on the opposite side. This has the advantage of reducing pavement cutting and service installation costs.

Street grades and main elevations should be taken into consideration so that mains once laid need not be disturbed by regrading. Even after every precaution has been taken in locating the pipelines, there are still occasions when they must be relocated or lowered.

Rights-of-Way

In the expansion of the existing highway systems under the federal government's aid program, and in constructing superhighways, water utilities are sometimes faced with enormous costs in carrying forward main-laying programs or in protecting existing installations. The relocation and abandonment of existing pipelines brought about by highway construction are resulting in high costs to many utilities. Utilities are reimbursed for such costs in some areas, but in many areas they are not.

Many utilities are finding it advisable to locate pipe in utility easements or in acquired rights-of-way. These easements are resorted to when savings can be realized in reduced pipe lengths, smaller installation costs, or the elimination of future relocation.

Design Sketches

For future use and to provide working plans, suitable sketches should be prepared prior to actual installation. The records necessary to initiate,

carry forward, and record main installations are described in more detail elsewhere in this manual. But from the initial sketches for the work to be performed, installation bids are solicited, pipe and fittings are ordered, permits are obtained, and deposit agreements are prepared along with other preliminary work. The importance of maps and sketches cannot be overemphasized. They should be as accurate as possible without excess detail.

Installation

The installation of water mains involves transporting and handling the pipe and appurtenances; ditching and excavation; laying, joining, testing, and disinfecting the pipe; backfilling the trench; and replacement of road, paving, and sidewalk surfaces. Complete specifications for the installation of pipe and fittings are given in an AWWA standard, C600.*

Excavation

Excavation can be carried out in several approved ways—by hand labor, power shovel, back hoe, or trenching machine. In many respects the back hoe has proved to be a good piece of equipment for installing pipe, particularly in the larger sizes. It is effective in doing the excavation, and can handle the pipe from the trench side to its completed installation.

The trench should be opened only so far in advance of pipe installation as is necessary. It is best to keep the trench as narrow as possible and to shape the bottom of the trench to form a complete bed. Blocking should preferably not be used under pipe, but if it is used it should be removed as soon as preliminary tamping of fill around the pipe provides full bearing. If rock is encountered, or if the bottom material is undesirable for bedding, it should be excavated 6 in. below the grade and refilled with sand or fine gravel tamped in place.

Laying and Jointing of Pipe

When the trench is suitably prepared, the pipe must be lowered and joined. Care must be exercised in handling so that it is not damaged. Various pipe manufacturers give special instructions for the handling and jointing of their pipe.

Because the "shove in" or "roll on" pipe joints have largely replaced joints poured with lead, sulfur compounds, and cement, details of these older joints are not set forth here. Reference should be made to AWWA C600 for the details of making such joints.

Sulfur compound joints were commonly used for cast-iron pipe during the period 1920–50. Much trouble has been, and is being, experienced

* Tentative AWWA Standard for Installation of Cast-Iron Water Mains. Am. Wtr. Wks. Assn., New York (1954).

with joint failures and breakage of the bells of such joints under certain soil conditions. This is generally attributed to the expansion of the joint material, and much controversy has arisen concerning it. Not much can be done to correct such installations except at considerable expense. Bell clamps may be successful in stopping breakage or the joints can be cut out and refilled with some other joint material.

The joining of the pipe should be done carefully. Each type of pipe requires special joining procedures. The distinctive sound of a joint being "home" should be heard on pushing the pipe together. If rubber gaskets are used, an inspection of completed joints should be made with "feelers" or by some other method to insure that the gaskets are properly seated. The newer types of joints are usually pulled together with "come-alongs," bars, a back hoe, or a bucket and sling. The same methods are used in installing valves, fittings, and fire hydrants as with straight pipe.

Valves, Hydrants, and Fittings

Valves should be placed in some standard area, such as street or curb lines, to facilitate their location. A valve box should always be placed over a buried valve with its cover at the street grade. Geared valves sometimes have enclosed gear and grease cases and are placed directly in the ground. Large valves are often placed in brick or concrete vaults.

Fire hydrants should be so located as to be completely accessible to the fire department and yet, as far as possible, be protected from damage from vehicles and out of the path of pedestrians. Hydrant nozzles should be set to grade and not less than 12 in. above grade. They should be so pointed as to be accessible, but should be a sufficient distance back from curb lines to escape vehicle damage. Fire hydrants are now rarely connected to distribution mains except through properly gated 6-in. or larger hydrant laterals. Hydrants are made to be self-draining through drain ports when shut off. To accomplish this drainage, a pocket filled with gravel or crushed stone at least 2 ft in diameter should be provided under and around the hydrant base. In clay ground this pocket may need to be larger. The hydrant and lateral both should be braced or tied with rods to protect against shifting due to unbalanced water pressure.

Blocking or firmly positioning tees, bends, caps, plugs, hydrants, and other fittings is an important part of pipeline installation. Any unbalanced pressure in a pipeline must be counterbalanced with blocking or positive ties, inasmuch as many modern joints can easily be pulled apart.

Sleeves are often used in the assembly of valves in pipelines. Care should be taken that pipe is solidly together, or "spacers" should be provided to prevent lengthwise movement of the pipe resulting from the unbalanced pressure exerted by valve closure.

Backfill and Surface Restoration

After pipe, fittings, valves and other appurtenances are installed and inspected, a selected backfill is placed in the trench—that is, the backfill should be free from rock, large stones, cinders, or other unsuitable substances to avoid damage and to produce a dense, compact backfill. Backfill material should be tamped in layers around the pipe and for a height of at least 12 in. over the pipe barrel. If possible, joints should be left exposed until pressure and leakage tests are concluded. Where trench settlement is unimportant the remainder of the trench can be filled with excavated material pushed in by bulldozers and mounded over the pipe trench. In streets or other locations where settlement is undesirable, the backfill should be consolidated by tamping or by flooding with water to the top of the trench. Local highway regulations often dictate what the backfill shall consist of and what the methods used to place it should be.

Proper restoration of paving, sidewalks, lawns, or shrubbery is important, for the general public will remember the restoration and cleanup much longer than the reason for installing the invisible main.

Hydrostatic and Leakage Tests

Hydrostatic-pressure tests and tests for leakage should be made whenever possible, particularly on major installations. To make such tests each valved section of the main should be slowly filled with water and air should be expelled from the line through hydrants or taps made at the high points. The pressure test is usually made by means of pump and test gage and at a test pressure at least 50 per cent greater than the working pressure in the line. The test pressure should be maintained for at least 1 hr and an examination should be made of the line for visible leaks or pipe movement. Any obvious defects should be fixed before the leakage test is made.

The leakage test should be conducted after the pressure test is completed. Leakage tests are conducted by measuring, through a calibrated meter, the amount of water which enters the test section under normal working pressures for a period of at least 2 hr.

It is prescribed in AWWA C600 that *:

> No installation will be accepted until the leakage is less than the number of gallons per hour as determined by the formula:
>
> $$L = \frac{ND\sqrt{P}}{1{,}850}$$
>
> in which L is the allowable leakage in gallons per hour; N is the number of joints in the length of the pipeline tested; D is the nominal diameter of the pipe,

* Tentative AWWA Standard for Installation of Cast-Iron Water Mains. Am. Wtr. Wks. Assn., New York (1954).

in inches; and P is the average test pressure during the leakage test, in pounds per square inch gage.

Disinfection of Mains

Although precautions may have been taken during installation to keep the interior of pipe and appurtenances free from debris and contamination, flushing and disinfection of the main are carried out to insure that a safe, potable water is delivered to customers. The best precaution is to swab out the pipe before installation. The use of bulkheads at the termination of day's work prevents animals, insects, and surface drainage from entering the pipe during the night hours. In spite of precautions foreign substances will usually get into the pipe so flushing and sterilization are required.

A good flushing of the line under pressure should be carried out to remove any dirt and debris which may have entered the line.

Mains may be disinfected with calcium hypochlorite in granular or tablet form, chlorine gas, or liquid chlorine. The use of calcium hypochlorite is one of the safest and easiest methods. The required amount of the chemical is deposited in each pipe section as it is installed. Depending on the elapsed time before the main is disinfected, the calcium hypochlorite can lose some of its potency through exposure to the atmosphere. Another method is to apply a solution into the end of the main where the flow of water can distribute it throughout its length. After a 40–50 ppm chlorine is in the main it is allowed to stand for 24 hr. It should then be checked for residual chlorine which should be at least 25 ppm. If a satisfactory residual is obtained, a flow is induced to insure complete disinfection, and the main is completely flushed.

Also available for disinfection of pipelines is a portable injector for chlorine gas. It can deliver large amounts of chlorine and is especially useful in sterilizing larger mains. The rate of application can be controlled and the length of time for the injection process reduced. Portable units can be run by a gasoline engine where power is not available.

Still another method is the use of liquid chlorine cylinders. This method could be dangerous unless the injection is supervised by competent employees. After a reduction in pressure the liquid chlorine is injected into the main. A flow of water in the main is necessary to distribute the chlorine. Freezing of chlorine can occur if the rate of application is not properly controlled. The flushing of the main should be thorough to get rid of the heavily chlorinated water before the main is placed in service.

Cleaning of Pipe

Sediment Deposits

In most water distribution systems, it is necessary to clean out sand, turbidity deposits, and similar substances that settle out in the pipes when

the velocity of flow is not sufficient to keep them in suspension. A good flushing at high induced velocities once or twice a year usually removes the major part of such settlement. At times, however, if flushing has not been carried out at sufficiently close intervals, more positive methods of cleaning become necessary. One means of accomplishing this is to force, by water pressure and induced flow, a chain-covered, inflated rubber ball through the pipeline. The rotation of the ball and the scraping of the interior surface of the pipe by the chains stir up the more dense settled material and it is flushed out. Another method of accomplishing this is to use a pipe-cleaning instrument having spring-loaded steel scrapers. The instrument is forced along the pipeline by water pressure and scrapes up the deposited material so that it can be carried out ahead by the flushing action of the water.

Tuberculation and Scale

Another type of cleaning, often required in older, unlined cast-iron pipe, is the removal of tubercles and deposits produced by the corrosive action of the water on the bare metal of the pipe. Over the years these tubercles may grow by accretion to such an extent that they nearly fill the pipeline. There may be a combined buildup of tuberculation and coatings of chemical compounds present in the water, such as calcium carbonate and chlorites or iron and manganese deposits. The elimination of such growths and deposits requires mechanical cleaning with actual scrapers.

Slime Growths

The third type of pipeline deposit that must be periodically eliminated results from the growth of iron bacteria or slimes. Although sometimes hardly noticeable, these growths nevertheless produce greatly increased friction losses in the mains. They are generally more common in raw-water pipelines carrying unchlorinated water, as chlorination is frequently effective in eliminating them. Iron and manganese deposits frequently occur in cement-lined cast-iron, asbestos-cement, and concrete pipelines in distribution systems, however. The ball-and-chain cleaner or a similar instrument is usually effective in removing most of these deposits, although the scraper must occasionally be used.

Reasons for Main Cleaning

Cleaning is resorted to in order to reduce friction losses. Unlined cast-iron pipe, when new, has a Hazen-Williams coefficient ranging from 120 to 130. In a period of years the roughening of the interior surface of the pipeline and the reduction of the cross-sectional area produced by rusting, tuberculation, and deposition reach such an extent that twice as much head may be required to send a given quantity of water through the line. Cleaning is a method of restoring the interior surface to a condition ap-

proximating that of the new main. Experience has indicated, however, that cleaning such mains without lining them with protective coating at the same time is only a very temporary solution. Tuberculation recurs much faster after cleaning, with the result that the coefficient returns to its previous value in a very few years.

Coefficient tests should be run when it appears that undue pressure losses are occurring to determine whether cleaning should be resorted to. They should also be run before and after cleaning to determine its effectiveness.

Cleaning Methods

In the more positive methods of cleaning, the section of pipe to be cleaned is first isolated and then the customers' services are shut off. At the ends of each section to be cleaned a short section of pipe is removed—at the head end to insert the cleaning instrument and at the opposite end to flush out the material to be removed and to remove the cleaner. The head end is generally closed by removable couplings and pressure is applied back of the cleaner to propel it along the line. The discharge end is provided with a bend and section of pipe rising to the street level to dispose of the flushing water and sediment. After cleaning and rejoining the pipe, it is usually necessary to flush the side laterals and sometimes to blow out customers' services to remove any sediment that is lodged in them.

In-Place Lining of Pipe

Practical methods have been developed for lining unlined cast-iron pipe in place after cleaning, in order to insure the retention of the improved flow characteristics. In the smaller pipelines this is generally done by centrifugally applying cement lining with a machine and dolly pulled through the pipe. Machines have likewise been devised for lining larger pipe by centrifugally applying the cement mortar and smoothing it in place with rotating finishers.

There are firms that specialize in cleaning pipe and lining it in place. In most cases the cost of cleaning and lining in place is less than it would cost to install new pipe, particularly if pavement removal and replacement are involved.

Corrosion

The corrosion or deterioration of pipe materials is generally a form of chemical deterioration. There are a number of theories regarding the causes of corrosion. They may generally be classed as galvanic (bimetallic), electrolytic, stress, chemical, and biological.

When dissimilar metallic materials are placed in the presence of moisture, a galvanic cell is formed, producing an electrical circuit and generating

a flow between an anode and a cathode. According to the position of the two metals in activity series, metal is lost in one and carried to the other.

Electrolytic corrosion is very similar to galvanic corrosion, except for the source of the current flowing through the electrolyte. The current in galvanic corrosion is due to the potential difference between two dissimilar metals, whereas in electrolytic corrosion the current arises from stray currents from grounded connections or faulty electrical circuits. The moist soil and water act as the electrolyte. The pipe material alternately becomes the anode and cathode, depending upon the differences in potential, and corrosion of the iron results.

The other forms of corrosion may be electrochemical also. Chemical corrosion is an oxidation reduction process. Biological corrosion results from the action of chemicals produced by soil bacteria such as sulfur or iron bacteria.

Corrosion Control

Corrosion can be retarded by several methods. Cathodic protection is a means of retarding corrosion by reversing the normal flow of electrons and depositing material from an anode made of metal in the activity series above iron so that it will be sacrificed to plate out on the iron and thus prevent corrosion.

Coatings and linings are the most prevalent methods of providing corrosion control. These consist of (1) cement, (2) bituminous materials, (3) resins and lacquers, (4) paints, (5) galvanizing and metal plating and (6) production of a carbonate lining by proper pH control and water treatment.

Sometimes in asbestos-cement and concrete pipe, as well as in cement-lined cast-iron and steel pipe, the water may have such characteristics as to produce an undesirable chemical reaction with the lime in the cement. Many systems using these types of distribution pipe require that the lining be coated with a bituminous material to eliminate or reduce such action.

Emergency Repairs

Damages to a pipe system due to emergencies and disasters are unpredictable. Water system operators should be prepared to put a plan of repair into operation whenever needed. Every utility should have an effective plan to cover emergencies such as floods, landslides, fires, explosions, severe cold spells, earthquakes, and the usual problems such as split pipes, blown joints, and broken valves and hydrants.

Equipment should always be available and ready for emergency repairs. Excavating equipment, pavement breakers, pipe cutters, ditch pumps, chlorinating equipment, flood lights, generators, and welding equipment should be available in permanent stock or on an emergency basis through agreement with outside sources.

Many types of materials will be needed, such as spare pipe and fittings, repair clamps, bell joint clamps, and, particularly, sleeves and mechanical couplings. Spare parts for valves and hydrants, as well as a reasonable number of complete spare units, should be available.

Work crews should be trained to be alert and know how to tackle the various normal emergencies all systems experience at times. The rapidity in which repairs can be accomplished may be an important element in reducing damages and damage claims.

All of the precautions taken for new work, such as disinfection, flushing, and hydrostatic testing, should also be taken when making major repairs.

Cross-Connection Control

A cross connection is any physical connection, direct or indirect, which provides a potential opportunity for nonpotable water to enter a conduit, pipe, or receptacle containing potable water. Cross connections either in the distribution system or, more likely, in customers' piping or plumbing can allow contaminated water to enter drinking water. The existence of temporary or permanent cross connections is more extensive than is generally realized. Most cases of waterborne disease arising today are traced to cross connections between potable and nonpotable sources, and vigilance, particularly of customers' premises, is necessary to reduce or eliminate such occurrences.

Cross connections which, for one reason or another, become necessary should be made only with the approval and supervision of the health authority having jurisdiction. Means are available to provide an approved cross connection. Certain devices such as (1) air-relief valves and vacuum breakers designed to admit air and break any vacuum in the water lines. (2) flush valves and integral vacuum breakers that keep the valves closed when a vacuum exists, (3) swing connections that permit connection either to the public water supply or to the local source but not to both simultaneously, (4) air gaps, and (5) reduced-pressure connections. To eliminate any possibility of pollution, it would be better not to have any physical connection between an approved supply and one not approved.

CHAPTER 9

Supports for Pipe

AWWA Steel Pipe Committee Report

A report on design and installation of steel water pipe has been prepared by AWWA Committee 8310 D—Steel Pipe. The report is being published in installments (May 1961 issue, p. 632; June 1961 issue, p. 750; August 1961 issue, p. 1034), with the expectation that it will be reprinted as a unit when complete. Comment and discussion by readers are encouraged. Discussion should be addressed to the Editor of the JOURNAL.

PIPE is supported in various ways depending upon size, circumstances, and economics. Small pipe within buildings may be held by adjustable hangers or by brackets, or may be otherwise attached to building members. When subjected to temperature changes causing considerable longitudinal movement, steel pipe is frequently set on concave rollers. Data on adjustable hangers and rollers have been published (*1*).

Pipe acting as a self-supporting bridge may rest upon suitably padded concrete saddles (Fig. 9.1 and 9.2) or may be supported by means of ring girders or flange rings welded to the pipe (Fig. 9.3–9.11). The kind of support selected may be determined by conditions of installation or by economics. The pipe cost is usually lower when saddles can be used and there is more flexibility in field erection. Ring girder construction adds to pipe fabrication costs, but longer, clear spans may be possible.

9.1. Saddle Supports

There has been very little uniformity in the design or spacing of saddle supports. The spans have been gradually increased, however, as experience has shown that such increases were safe and practical.

In general, the ordinary theory of flexure applies when a circular pipe is supported at intervals, is held circular at and between the supports, and is completely filled. If the pipe is only partially filled and the cross section at points between supports becomes out-of-round, the maximum fiber stress is considerably greater than indicated by the ordinary flexure formula, and is highest for the half-filled condition (*2*).

In the case of a pipe carrying internal pressure where the ends are fully restrained, the Poisson ratio effect of the hoop stress, which produces lateral tension, must be added to the flexural stress to obtain the total beam stress.

Excessive deflection should be avoided when pipe acts as a beam. A maximum deflection of $\frac{1}{360}$ of the span is suggested as good practice. This is the same as is used for beams carrying plastered ceilings.

Saddle supports cause high local stresses both longitudinally and cir-

cumferentially in unstiffened, comparatively thin wall pipe at the tips and edges of the supports. Stresses vary with the load, with the diameter–wall thickness ratio, and with the angle of contact with the pipe. In practice, the contact angle varies from 90 to 120 deg. The difficulty encountered with 180-deg contact angles has been eliminated by reducing the angles to 120 deg. For equal load, the stresses are less for a large contact angle than for a small one, and, contrary to general belief, their intensity is practically independent of the width of the saddle (Dimension B, Fig. 9.1). The width of the saddle may therefore be that which is most desirable from the standpoint of good pier design.

Because saddle supports cause critical points of stress in the metal adjacent to the saddle edges, it is frequently more economical to increase the wall thickness of the pipe when it is overstressed than to provide stiffening rings. This is especially true where pipe sizes are 36 in. in diameter and smaller. Even a small increase in wall thickness has a great stiffening effect. The whole length of the span may be thickened, or, alternatively, only a length at the saddle support—equal to about two pipe diameters plus saddle width—need be thickened.

When pipe lengths resting on saddles are joined by flanges or mechanical couplings, the strength and position of the joints must be such that they

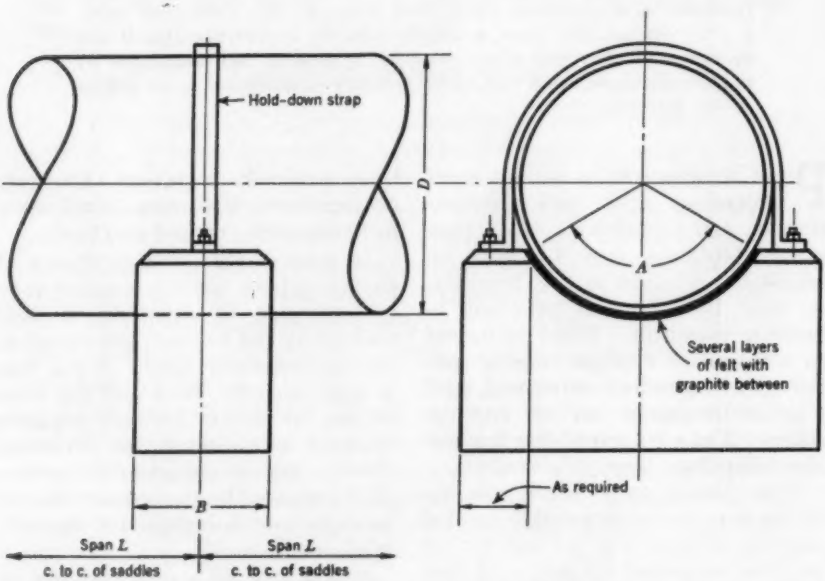

Fig. 9.1. Details of Concrete Saddle

Pipe acting as a self-supporting bridge may rest on suitably padded concrete saddles (16).

will safely resist the bending and shear forces while remaining tight. Ordinarily it is advisable to place joints at, or as near as practicable to, the point of zero bending moment in the span or spans. Manufacturers of mechanical joints should be consulted regarding the use of their joints on self-supporting pipe spans.

The pipe should be held in each saddle by a steel holddown strap bolted to the concrete. Secure anchorages must be provided at intervals in multiple-span installations.

The ability of steel pipe to resist saddle load has sometimes been greatly underestimated by designers. Unnecessary expense has thus been entailed, because more supports have been provided than may have been necessary. According to one authority (*2*), the maximum value of the *localized* stresses in a pipe which fits the saddle well probably does not exceed that given by the formula,

$$S_l = k\frac{P}{t^2}\log_e\frac{R}{t} \quad \ldots\ldots\ldots (9.1)$$

in which S_l represents the localized stress (psi), P the total saddle reaction (lb), R the pipe radius (in.), t the pipe wall thickness (in.), and $k = 0.02 - 0.00012\,(A - 90)$, in which A is in degrees (see Fig. 9.1 for A). The maximum saddle reaction a pipe can stand is about twice the value of P (Eq 9.1) when S_l equals the yield point of the steel used. Equation 9.1 does not account for temperature stresses.

Table 9.1 gives values of P for some sizes and wall thicknesses of pipe for a 1,000-lb increment of stress S_l. Column 3 applies when 90-deg contact saddles are used, and Column 4 when the contact angle is 120 deg. Loads are directly proportional for intermediate values of S_l.

To the localized stress, S_l, must be added certain other stresses to determine the total stress. Let:

S_f = flexure stress in span with pipe having *unrestrained* ends
S_p = ring stress due to internal water pressure
$S_b = S_f + 0.25S_p$ = maximum beam stress in span with pipe having *restrained* ends
$S_b = S_f$ for pipe with *unrestrained* ends
S_l = localized stress at saddle
S_t = maximum stress at saddle.

Then, for single or multiple spans *of uniform thickness*,

$$S_t = S_b + S_l \quad \ldots\ldots\ldots (9.2)$$

It should be noted that S_t is the maximum stress at the *saddle*. Any pipe selected must meet two requirements: the maximum beam stress, S_b, in the span must be within the allowable limit, and the maximum stress at the saddle also must be within the allowable limit. One or the other will govern.

The flexure stress, S_f, should be calculated in the usual manner. In single spans, this stress is maximum at the center between supports and may be quite small over the support if flexible joints are used at the pipe ends. In multiple-span cases, the flexure stress in rigidly joined pipe will be that indicated by the theory of continuous beams.

Tables 9.1 and 9.2 have been prepared to aid in solving problems of self-supporting pipe spans for pipe of 36-in. diameter and smaller. For pipe with diameters of 24–96 in., Table 9.3 gives practical safe spans which may be on the conservative side. Data for calculating spans for large pipe on saddles have been published (*3*).

TABLE 9.1

Data on Saddle Loads, Pipe Weights, and Spans

1	2	3	4	5	6	7	8	9	10	11
OD in.	Wall Thickness in.	Values of P for $S_f = 1{,}000$ psi		Weight of Pipe and Water lb/ft	Values of Span L for S_f as Shown					
		$A = 90°$	$A = 120°$		S_f 2,500	S_f 5,000	S_f 7,500	S_f 10,000	S_f 12,500	S_f 15,000
6⅝	0.141	315	385	25	18	25	31	36	40	44
	0.188	615	750	28	20	29	35	41	46	50
	0.250	1,200	1,480	32	22	32	39	45	50	55
8⅝	0.141	290	350	38	18	25	31	36	40	44
	0.188	560	685	42	21	30	36	42	47	51
	0.250	1,070	1,310	47	23	33	40	46	51	56
10¾	0.188	525	640	59	22	31	38	44	49	54
	0.250	1,020	1,240	66	23	33	41	47	52	58
	0.312	1,710	2,080	70	26	37	45	52	58	64
12¾	0.188	500	610	80	22	32	39	45	50	55
	0.250	960	1,180	88	24	35	42	49	55	60
	0.312	1,610	1,970	97	27	38	47	54	60	66
14	0.188	490	595	95	22	32	39	45	50	55
	0.250	940	1,140	104	24	35	42	49	55	60
	0.312	1,560	1,900	113	27	38	47	54	60	66
16	0.188	470	570	119	23	33	40	46	51	56
	0.250	900	1,100	129	25	35	43	50	56	61
	0.312	1,500	1,830	139	27	39	47	55	61	67
18	0.188	460	560	147	23	33	41	47	52	58
	0.250	870	1,060	158	25	36	44	51	57	62
	0.312	1,450	1,770	170	28	40	48	56	63	68
20	0.188	440	540	176	24	34	42	48	54	59
	0.250	850	1,030	189	26	37	45	52	58	64
	0.312	1,400	1,710	212	29	41	50	58	65	71
24	0.188	425	520	244	25	35	43	50	56	61
	0.250	810	985	259	27	38	47	54	60	66
	0.375	2,030	2,470	291	31	44	54	62	69	76
30	0.250	765	930	385	28	40	48	56	63	68
	0.375	1,900	2,320	425	32	45	55	64	71	78
	0.500	3,670	4,480	464	35	50	61	71	79	87
36	0.250	730	890	536	28	40	49	57	64	70
	0.375	1,810	2,210	584	33	47	57	66	74	81
	0.500	3,490	4,250	631	36	52	63	73	81	89

TABLE 9.2

Ring Stress for Given Pressure

1	2	3	4	5	6	7	8
OD *in.*	Wall Thickness *in.*	Ring Stress, S_p, for Internal Pressure (psi) as Shown					
		$p = 50$	$p = 75$	$p = 100$	$p = 150$	$p = 200$	$p = 250$
6⅝	0.141	1,170	1,760	2,350	3,520	4,700	5,870
	0.188	880	1,320	1,760	2,640	3,520	4,410
	0.250	660	990	1,320	1,980	2,640	3,310
8⅝	0.141	1,530	2,290	3,060	4,580	6,110	7,640
	0.188	1,150	1,720	2,290	3,440	4,580	5,740
	0.250	860	1,290	1,720	2,580	3,440	4,320
10¾	0.188	1,430	2,140	2,860	4,280	5,710	7,140
	0.250	1,080	1,610	2,150	3,220	4,300	5,380
	0.312	860	1,290	1,720	2,580	3,440	4,300
12¾	0.188	1,690	2,540	3,390	5,080	6,780	8,480
	0.250	1,280	1,910	2,550	3,820	5,100	6,380
	0.312	1,020	1,540	2,045	3,070	4,090	5,120
14	0.188	1,850	2,780	3,720	5,560	7,420	9,280
	0.250	1,400	2,100	2,800	4,200	5,600	7,000
	0.312	1,120	1,680	2,240	3,360	4,480	5,610
16	0.188	2,130	3,180	4,260	6,380	8,520	10,640
	0.250	1,600	2,390	3,200	4,780	6,390	7,980
	0.312	1,280	1,930	2,560	3,860	5,140	6,420
18	0.188	2,390	3,580	4,790	7,160	9,550	11,950
	0.250	1,800	2,690	3,600	5,380	7,180	8,980
	0.312	1,440	2,160	2,880	4,320	5,760	7,200
20	0.188	2,680	3,990	5,320	7,980	10,620	13,290
	0.250	2,000	3,000	4,000	6,000	8,000	10,000
	0.312	1,600	2,400	3,210	4,800	6,400	8,000
24	0.188	3,180	4,760	6,370	9,540	12,720	15,890
	0.250	2,390	3,580	4,790	7,160	9,550	11,950
	0.375	1,600	2,390	3,200	4,780	6,390	7,980
30	0.250	2,990	4,480	5,990	8,960	11,900	14,950
	0.375	2,000	3,000	4,000	6,000	8,000	10,000
	0.500	1,500	2,250	3,000	4,500	6,000	7,500
36	0.250	3,600	5,390	7,190	10,790	14,380	17,980
	0.375	2,390	3,580	4,790	7,160	9,550	11,950
	0.500	1,800	2,690	3,600	5,380	7,180	8,980

From Barnard (16)

When Tables 9.1 and 9.2 are used, the solution is found by trial and error. First, assume a wall thickness for which S_f is about 10,000 psi when the span is somewhat greater than required. Interpolate S_f for span desired. Find S_p from Table 9.2 and determine S_b. It should not exceed the allowable maximum stress. Determine the reaction load for the span desired, using Column 5 of Table 9.1. Then determine S_l using the data in Column 3 or 4 of Table 9.1. Add S_l and S_b. This gives S_t, which should also not exceed the allowable maximum stress. If it does, there are two alternatives: either a thicker wall may be selected for the whole pipe and the smaller value of S_t recalculated, which should then satisfy the stress requirement; or else, a thinner wall may be selected for the main span and a heavier wall for a distance of two pipe diameters plus saddle width over the saddle. In the latter case, the S_b to be used in determining the total localized stress, S_t, is that which would exist if the thicker-wall pipe were used for the whole span.

Fig. 9.2. Saddle Supports for 36-in. Pipe

Adjustable forms for last-operation grouting are beneath the pipe, at the top of some piers.

9.2. Pipe Deflection as Beam

In the design of free spans of pipe, it may be desirable to determine the theoretical deflection in order to judge flexibility or ascertain that the

deflection does not exceed a desirable upper limit.

Freely supported pipe sometimes must be laid so that it will drain fully and contain no pockets between supports. The deflection or sag between supports must be found to determine the necessary grade.

In any given case, the deflection is influenced by conditions of installation. The pipe may be a single span or may be continuous over several supports. The ends may act as though free or as though fixed. The pipe may carry gas or liquid and, in addition to its own weight and that of its contents, may carry the weight of insulation or other uniform load. Concentrated loads such as valves and fittings may be present between supports.

The maximum theoretical deflection can be determined using:

$$y = 22.5 \frac{WL^3}{EI} \quad \text{.....(9.3)}$$

in which:

y = maximum deflection at center of span (in.)

TABLE 9.3

*Practical Safe Spans for Simply Supported Pipe in 120-deg Contact Saddles**

Nominal Size *in.*	Wall Thickness—*in.*									
	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
	Span, *L*—*ft*									
24	33.4	37.4	40.5	43.0	45.2	47.0				
26	33.7	37.7	41.0	43.6	45.9	47.8				
28	33.9	38.1	41.4	44.1	46.5	48.5				
30	34.2	38.4	41.9	44.8	47.2	49.4				
32	34.4	38.7	42.2	45.2	47.7	50.0				
34	34.5	38.9	42.5	45.5	48.2	50.4				
36	34.7	39.1	42.8	45.9	48.6	50.9	54.8			
38	34.8	39.3	43.0	46.2	48.9	51.3	55.4			
40	34.9	39.5	43.3	46.5	49.2	51.7	55.9			
42	35.0	39.6	43.5	46.7	49.6	52.1	56.3			
45		39.8	43.7	47.1	50.0	52.5	56.9			
48		40.0	44.0	47.4	50.4	53.0	57.5	61.2		
51		40.2	44.2	47.7	50.7	53.4	58.0	61.8		
54		40.4	44.4	47.9	51.0	53.7	58.4	62.4		
57		40.5	44.6	48.2	51.3	54.1	58.9	62.9		
60		40.6	44.8	48.4	51.5	54.4	59.2	63.3	66.8	69.9
63		40.7	44.9	48.6	51.8	54.6	59.6	63.8	67.4	70.5
66		40.8	45.1	48.7	52.0	54.9	59.9	64.2	67.8	71.0
72		41.0	45.3	49.0	52.4	55.3	60.5	64.9	68.7	72.0
78		41.2	45.5	49.3	52.7	55.7	61.0	65.5	69.4	72.9
84		41.3	45.7	49.6	53.0	56.1	61.5	66.1	70.1	73.6
90		41.4	45.9	49.8	53.2	56.4	61.9	66.6	70.7	74.3
96		41.6	46.0	50.0	53.5	56.6	62.2	67.0	71.2	75.0

* After Cates (*10*): Span $L = \sqrt{\frac{7{,}500dt}{32t + d}}$, in which d and t are pipe diameter and thickness, respectively (in inches), and L is in feet.

W = total load on span (lb)
L = length of span (ft)
E = modulus of elasticity (psi) (30,000,000 for steel pipe)
I = moment of inertia of pipe (in.^{4}) (values of I are given in Table 9.4).

Except for some changes in unit designation, this is the standard textbook formula for *uniformly distributed* load and *free ends*. It can be used for *concentrated* loads at the center of the span, and for *other end conditions* less than that determined theoretically for a uniformly loaded pipe fixed at both ends. The deflection of smaller pipe approached the theoretical for free ends.

The following methods of calculating deflection are based on the formulas commonly found in textbooks for the cases given.

9.3. Methods of Calculation

Maximum deflection in a given case can be calculated by first assuming

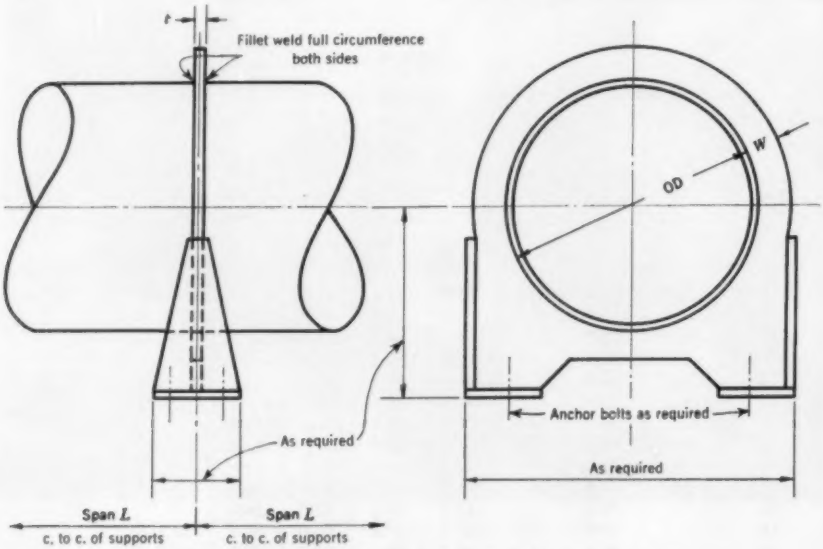

Fig. 9.3. Details of Ring Girder Support for Small Pipe

These girders prevent the distortion of the pipe at the points of support (16).

by applying a correction factor as described later.

Tests conducted to determine the deflection of horizontal standard-weight pipelines filled with water (*1*) have indicated that the deflection of pipe larger than 2 in. and supported at intervals greater than 10 ft is

that the load is uniformly distributed and the ends are free. This is Case 1 below. Later this result can be modified if the load is concentrated or the ends are fixed (Cases 2, 3, and 4 below). The deflection for Case 1 may be calculated using Eq 9.3. Note that, in Cases 1 and 2, the load,

W, is the total *uniformly distributed* load on the span but that, in Cases 3 and 4, it is the load *concentrated* at the center of the span.

The four most commonly encountered conditions, with their corresponding deflection factors, are:

Case 1. If the load, W, is uniformly distributed and the ends are free, the deflection is as calculated using Eq 9.3.

Case 2. If the load, W, is uniformly distributed but the ends are fixed, the deflection is 0.2 times that for Case 1.

Case 3. If the load, W, is concentrated at the center and the ends are free, the deflection is 1.6 times that for Case 1.

Case 4. If the load, W, is concentrated at the center and the ends are fixed, the deflection is 0.4 times that for Case 1.

The deflections caused by different loads are additive. Therefore, if a uniformly loaded pipe span contains a concentrated load, the calculated deflection for the latter is added to that for the uniform load, and the total sag in the pipe is the sum of the two deflections.

9.4. Gradient of Supported Pipelines to Prevent Pocketing

If intermittently supported pipelines are to drain freely, they must contain no sag pockets. To eliminate pockets, each downstream support level must be lower than its upstream neighbor by an amount which is dependent upon the sag of the pipe between them. A practical average gradient of support elevations to meet this requirement may be found by using the following formula (*4*):

$$G = \frac{L}{4y} \quad \ldots\ldots\ldots\ldots (9.4)$$

in which:

G = grade (1 in. in G ft)
L = span (ft)
y = deflection (in.).

Example: If the deflection of an insulated, 20-in. OD, 0.375-in. wall pipe carrying steam is 0.4 in. in a simple, free-ended 50-ft span, what should be the grade of a series of 50-ft spans to allow drainage?

Solution:

$$G = \frac{50}{4(0.4)} = 31$$

The grade therefore is 1 in. in 31 ft.

Fig. 9.4. Ring Girder Support of 30-in. Pipe

Ring girders provided support for this 30-in. diameter pipe with $\frac{3}{8}$-in. wall and a span of 65 ft across a river.

It has been suggested (*1*) that, in the interest of satisfactory operation, it is well to double the calculated theoretical deflection when determining the slope of the pipeline gradient. If this were done in the preceding example, the grade used would be 1 in. in 15.5 ft.

The difference in elevation between a downstream support and its upstream neighbor must be four times the theoretical deflection of the pipe

TABLE 9.4

Values of Moment of Inertia and Section Modulus of Steel Pipe

Nominal Size* in.	Wall Thickness in.	Moment of Inertia in.⁴	Section Modulus cu in.	Nominal Size* in.	Wall Thickness in.	Moment of Inertia in.⁴	Section Modulus cu in.
4	0.105	2.44	1.22	18	0.179	397.88	44.21
4	0.135	3.06	1.53	18	0.188	416.18	46.24
4½	0.105	3.50	1.56	18	0.239	525.94	58.44
4½	0.135	4.41	1.96	18	0.250	549.14	61.02
6	0.105	8.45	2.82	18	0.312	679.28	75.48
6	0.135	10.70	3.57	20	0.135	415.60	41.56
6	0.188	14.47	4.82	20	0.179	547.43	54.74
6	0.219	16.63	5.54	20	0.188	572.69	57.27
6⅝	0.105	11.43	3.45	20	0.239	724.35	72.44
6⅝	0.135	14.50	4.38	20	0.250	756.44	75.64
6⅝	0.188	19.66	5.94	20	0.312	936.68	93.67
6⅝	0.219	22.62	6.83	20	0.375	1,113.47	111.35
8	0.105	20.29	5.07	22	0.179	730.41	66.40
8	0.135	25.80	6.45	22	0.188	764.21	69.47
8	0.179	33.65	8.41	22	0.239	967.27	87.93
8	0.188	35.13	8.78	22	0.250	1,010.27	91.84
8	0.239	43.92	10.98	22	0.312	1,252.07	113.82
8⅝	0.105	25.51	5.91	22	0.375	1,489.67	135.42
8⅝	0.135	32.45	7.52	24	0.179	950.21	79.18
8⅝	0.179	42.37	9.83	24	0.188	994.27	82.86
8⅝	0.188	44.25	10.26	24	0.239	1,259.21	104.93
8⅝	0.239	55.40	12.85	24	0.250	1,315.35	109.61
10	0.135	50.91	10.18	24	0.312	1,631.34	135.94
10	0.179	66.61	13.32	24	0.375	1,942.30	161.86
10	0.188	69.59	13.92	24	0.438	2,248.29	187.36
10	0.239	87.34	17.47	24	0.500	2,549.36	212.45
10¾	0.135	63.42	11.80	26	0.179	1,210.19	93.09
10¾	0.179	83.06	15.45	26	0.188	1,266.41	97.42
10¾	0.188	86.80	16.15	26	0.239	1,604.67	123.44
10¾	0.239	109.05	20.29	26	0.250	1,676.38	128.95
12	0.135	88.56	14.76	26	0.312	2,080.37	160.03
12	0.179	116.14	19.36	26	0.375	2,478.43	190.65
12	0.188	121.39	20.23	26	0.438	2,870.62	220.82
12	0.239	152.75	25.46	26	0.500	3,257.00	250.54
12¾	0.135	106.44	16.70	28	0.179	1,513.74	108.12
12¾	0.179	139.67	21.91	28	0.188	1,584.17	113.16
12¾	0.188	146.01	22.90	28	0.239	2,008.15	143.44
12¾	0.239	183.86	28.84	28	0.250	2,098.09	149.86
14	0.135	141.32	20.19	28	0.312	2,605.06	186.08
14	0.179	185.61	26.52	28	0.375	3,105.12	221.79
14	0.188	194.07	27.72	28	0.438	3,598.36	257.03
14	0.239	244.65	34.95	28	0.500	4,084.82	291.77
16	0.135	211.71	26.46	30	0.188	2,025.63	133.37
16	0.179	278.40	34.80	30	0.250	2,717.73	178.21
16	0.188	291.16	36.39	30	0.312	3,418.40	223.24
16	0.239	367.54	45.94	30	0.375	4,127.69	268.47
16	0.250	383.66	47.96	30	0.438	4,845.69	313.89
16	0.312	473.96	59.25	30	0.500	5,572.46	359.51
18	0.135	302.29	33.59	32	0.188	2,455.49	151.69

* Sizes under 30 in. are OD sizes; those 30 in. and over are ID sizes.

TABLE 9.4—*Values of Moment of Inertia and Section Modulus of Steel Pipe (contd.)*

Nominal Size* *in.*	Wall Thickness *in.*	Moment of Inertia *in.*⁴	Section Modulus *cu in.*	Nominal Size* *in.*	Wall Thickness *in.*	Moment of Inertia *in.*⁴	Section Modulus *cu in.*
32	0.250	3,293.19	202.66	48	0.500	22,402.80	914.40
32	0.312	4,140.60	253.83	48	0.625	28,222.24	1,146.08
32	0.375	4,997.81	305.21	48	0.750	34,130.98	1,379.03
32	0.438	5,864.89	356.80	51	0.250	13,215.78	513.23
32	0.500	6,741.92	408.60	51	0.312	16,580.45	642.34
34	0.188	2,942.23	171.18	51	0.375	19,969.67	771.77
34	0.250	3,944.63	228.67	51	0.438	23,383.52	901.53
34	0.312	4,957.97	286.38	51	0.500	26,822.15	1,031.62
34	0.375	5,982.35	344.31	51	0.625	33,774.18	1,292.79
34	0.438	7,017.84	402.46	51	0.750	40,826.72	1,555.30
34	0.500	8,064.54	460.83	54	0.250	15,675.07	575.23
36	0.188	3,489.39	191.86	54	0.312	19,661.86	719.88
36	0.250	4,676.77	256.26	54	0.375	23,676.13	864.88
36	0.312	5,876.40	320.90	54	0.438	27,717.97	1,010.22
36	0.375	7,088.39	385.76	54	0.500	31,787.54	1,155.91
36	0.438	8.312.80	450.86	54	0.625	40,010.33	1,448.34
36	0.500	9,549.73	516.20	54	0.750	48,345.50	1,742.18
36	0.625	12,061.47	647.60	57	0.250	18,421.95	640.76
38	0.188	4,100.49	213.71	57	0.312	23,103.18	801.85
38	0.250	5,494.32	285.42	57	0.375	27,814.98	963.29
38	0.312	6,901.78	357.37	57	0.438	32,557.47	1,125.10
38	0.375	8,322.98	429.57	57	0.500	37,330.80	1,287.27
38	0.438	9,746.46	501.44	57	0.625	46,970.46	1,612.72
38	0.500	11,206.92	574.71	57	0.750	56,735.04	1,939.66
38	0.625	14,146.86	720.86	60	0.250	21,472.35	709.83
40	0.188	4,779.08	236.73	60	0.312	26,924.30	888.22
40	0.250	6,401.99	316.15	60	0.375	32,410.10	1,067.00
40	0.312	8,040.00	395.82	60	0.438	37,929.85	1,246.16
40	0.375	9,693.20	475.74	60	0.500	43,483.72	1,425.70
40	0.438	11,348.28	555 28	60	0.625	54,694.33	1,785.94
40	0.500	13,045.54	636.37	60	0.750	66,043.06	2,147.74
40	0.625	16,459.77	798.05	60	0.875	77,531.04	2,511.13
42	0.188	5,528.68	260.94	60	1.000	89,159.39	2,876.11
42	0.250	7,404.51	348.45	63	0.250	24,842.16	782.43
42	0.312	9,296.95	436.22	63	0.312	31,145.10	979.02
42	0.375	11,206.12	524.26	63	0.375	37,485.33	1,176.01
42	0.438	13,132.11	612.58	63	0.438	43,862.94	1,373.40
42	0.500	15,075.02	701.16	63	0.500	50,278.12	1,571.19
42	0.625	19,011.99	879.17	63	0.625	63,221.71	1,967.99
45	0.250	9,096.41	399.84	63	0.750	76,317.27	2,366.43
45	0.312	11,417.88	500.51	63	0.875	89,566.00	2,766.52
45	0.375	13,758.52	601.47	63	1.000	102,969.0	3,168.28
45	0.438	16,118.42	702.71	66	0.250	28,547.28	858.56
45	0.500	18,497.69	804.25	66	0.312	35,785.46	1,074.24
45	0.625	23,324.77	1,008.21	66	0.375	43,064.52	1,290.32
48	0.250	11,028.20	454.77	66	0.438	50,384.57	1,506.83
48	0.312	13,839.09	569.22	66	0.500	57,745.80	1,723.76
48	0.375	16,671.75	683.97	66	0.625	72,592.34	2,158.88
48	0.428	19,526.28	799.03	66	0.750	87,605.39	2,595.72

* Sizes under 30 in. are OD sizes; those 30 in. and over are ID sizes.

between them to establish the grade according to Eq 9.4. The elevation difference is eight times the deflection if the suggestion in the preceding paragraph is followed.

9.5. Examples of Saddle Support Calculations

Problem 1. A 30-in. pipe carrying 150 psi pressure is to span 65 ft over a single opening using 120-deg contact saddles. Determine its thickness in the span and at the saddle supports so that neither S_b nor S_t exceeds 18,000 psi when ends are considered restrained (see Sec. 9.1).

Solution. From Column 9 of Table 9.1, L is 64 ft for a wall thickness of 0.375 in. and $S_f = 10{,}000$; and from Column 10, L is 71 ft for $S_f = 12{,}500$. For practical purposes, S_f for $L = 65$ ft may be determined by interpolation. On this basis, $S_f = 10{,}360$.

From Table 9.2, S_p for 150 psi is 6,000. Then $0.25S_p = 1{,}500$, and $S_b = 10{,}360 + 1{,}500 = 11{,}860$, which is less than 18,000.

From Column 5 of Table 9.1, the weight of the pipe and contained water is 425 lb/lin ft. (Any additional live or dead load must be added.) The total reaction at one saddle is $32.5 \times 425 = 13{,}800$ lb. (Note: if the design requires the saddle to carry a portion of the approach span weight, this should be added.) From Column 4 of Table 9.1, it is seen that 2,320 lb of reaction is resisted by each 1,000 psi of stress S_t. Therefore:

$$S_t = \frac{13{,}800}{2{,}320} \times 1{,}000 = 5{,}950.$$

Then $S_t = 11{,}860 + 5{,}950 = 17{,}810$ psi, and, as this is less than the 18,000-psi maximum fixed, the 30-in.,

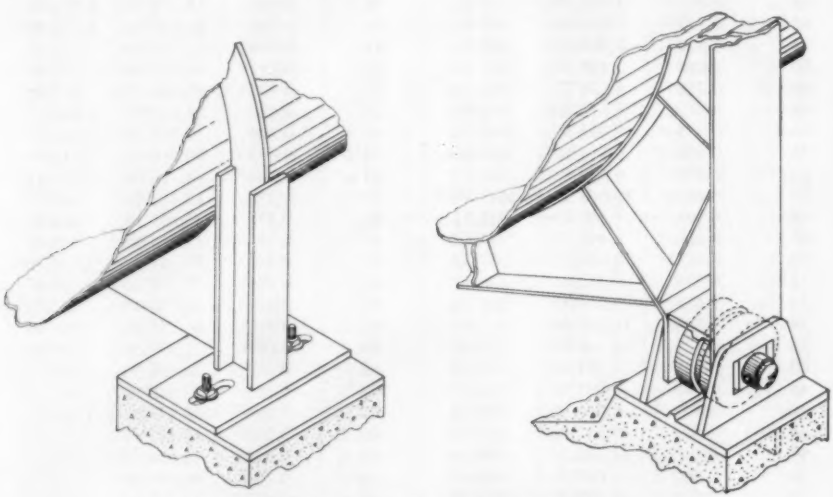

Fig. 9.5. Details of Ring Girder Support for Large Pipe

The illustration at the left shows the simplest type of support; at the right is a roller support (15).

0.375-in.-thick wall pipe meets the requirements.

The calculated deflection is $1\frac{1}{2}$ in., which is considerably less than $\frac{1}{360}$ of the span—$2\frac{3}{16}$ in.

Problem 2. Can 30-in. pipe with 0.25-in. wall be used for the central portion of the above span if thickened at the saddle?

Solution. From Column 10 of Table 9.1, L is 63 ft for $S_f = 12{,}500$ and 68 ft for $S_f = 15{,}000$. By interpolation, $S_f = 13{,}500$ for $L = 65$ ft. From Column 6 of Table 9.2, $S_p = 8{,}960$. Then $0.25S_p = 2{,}240$ and $S_b = 13{,}500 + 2{,}240 = 15{,}740$. As this is less than the 18,000 maximum specified, the 0.25-in. wall pipe may be used in the span, but it is obvious that it must be thickened over the saddle.

Assume 0.375-in. thick pipe over the saddle. The saddle reaction from Column 5 of Table 9.1 is $32.5 \times 385 = 12{,}500$, and the corresponding stress,

$$S_t = \frac{12{,}500}{2{,}320} \times 1{,}000 = 5{,}400.$$

For practical purposes, the effective S_b which is to be added may be conservatively considered the same as if the 0.375-in. pipe continued across the span. From Problem 1, $S_b = 11{,}860$. Therefore, $S_t = 11{,}860 + 5{,}400 = 17{,}260$, and, by using 0.375-in.-thick pipe over the support, the balance may be 0.25-in. thick.

The maximum saddle stress exists only a few inches from the edge of the saddle, but, to be conservative, it is suggested that the heavier pipe extend one pipe diameter on each side of the support.

The calculated deflection is 2 in., which is less than the $2\frac{3}{16}$-in. suggested maximum.

TABLE 9.5

Critical Wrinkling Stresses for Established Installations as Determined by Two Methods

Location of Installation	Diam. *ft*	*t* *in.*	Span *ft*	Ratio *t/r*	Critical		
					Strain* ϵ	Stress† Fig. 1.4	Stress $0.12Et/r$
Kungsfor, Sweden	9.0	$\frac{5}{16}$	38	0.0058	0.00087	26,500	20,900
Sweden (common practice)	12.5	$\frac{1}{4}$	43	0.003	0.00050	15,000	11,900
Los Angeles Aqueduct, Calif.	10.0	$\frac{1}{4}$		0.0042	0.00063	18,500	15,100
Santeetlah, N.C.	11.0	$\frac{3}{8}$	30	0.0057	0.00085	25,500	20,500
Atrafors, Sweden	13.1	$\frac{7}{32}$	44.2	0.0028	0.00042	12,000	10,100
Rempen, Switzerland	7.2	$\frac{3}{4}$	73.5	0.0170	0.0026	33,000	33,000
Soledad Siphon, Calif.	10.0	$\frac{1}{2}$	115	0.0083	0.0013	31,500	30,000

* Strain $\epsilon = 0.25 \times 0.60t/r$.
† Stress read from Fig. 1.4, Chap. 1, corresponding to strain ϵ.

9.6. Support of Mechanically Coupled Pipelines Above Ground

Data on size and pressure limits for mechanically coupled pipe on support saddles have been published (*5*).

9.7. Ring Girder Construction

When large-diameter steel pipe is laid aboveground or across ravines or

streams, rigid ring girders, spaced at relatively long intervals, have been found to be very effective supports. These girders prevent the distortion of the pipe at the points of support and thus maintain its ability to act as a beam. Details and installations are shown in Fig. 9.3–9.11. Generally, practical considerations limit the spans to 40–100 ft.

A satisfactory, rational design for ring girder construction, based on the elastic theory, was presented by Herman Schorer (*3*). The following nomenclature, interpreted by Fig. 9.10, is used in the design equations. Units must be consistent—for instance, inches, pounds, pounds per square inch, or pounds per cubic inch:

a = eccentricity of the reaction $\frac{Q}{2}$ from tangent to centroidal axis of stiffener ring having radius R (in.)
C = contact width of circular girder ring of rectangular cross section (in.)
C' = $1.56\sqrt{rt} + t_w$ (see Fig. 9.10c) if shell is used as combined section with stiffener girder web or if additional plate reinforcement is used at contact face
f_r = maximum combined ring stress in shell
f_L = combined maximum longitudinal beam stress
f_{bo} = maximum longitudinal rim bending stress in shell
h = head above bottom of pipe (ft)
p = variable pressure on inside of pipe circumference
q = unit weight of fluid flowing in pipe (lb/cu ft)
r = mean radius of pipe shell (in.)
t = thickness of pipe shell (in.)
w = weight of pipe shell per unit of area (psf)
A_r = area of supporting ring (see Fig. 9.10b) (sq in.)
D = diameter of pipe = $2r$ (in.)
L = length of span from center to center of ring girder supports (ft)
Q = total load of pipe shell transmitted by shear to one ring girder (lb)
y = distance from neutral axis to extreme fiber (in.)
I = moment of inertia. (in.^{4}).

9.7.1. Stress in Pipe Shell

The maximum combined ring stress is:

$$f_r = \frac{D}{2t}(w + qh) \quad \ldots\ldots (9.5)$$

The combined maximum longitudinal stress (for free-end beam conditions) is:

$$f_L = \frac{L^2}{4t}\left(\frac{2w}{D} + \frac{q}{2}\right) \quad \ldots\ldots (9.6)$$

The maximum rim bending stress in the shell due to internal pressure is:

$$f_{bo} = \frac{1.82(A_r - Ct)}{A_r + 1.56t\sqrt{rt}} \cdot \frac{pr}{t} \quad \ldots\ldots (9.7)$$

This equation was developed on the assumption that the stiffener ring is integral with the pipe shell and that the rim load is symmetrical. As the rim load is not symmetrical, because of the weight of the water, a good approximation of the maximum value of f_{bo} is obtained by substituting the value of f_r from Eq 9.5 in place of $\frac{pr}{t}$.

If the girder ring is fitted to the pipe in a loose manner, the rim bending stress due to the reaction at the supports should be taken into account, because the load will be transmitted mostly by direct bearing on the lower

half of the ring rather than through shear distributed around the pipe.

The total combined longitudinal shell stress, f, is:

$$f = f_L + f_{bo} \quad \ldots\ldots\ldots (9.8)$$

9.7.2. Stress in Ring Girder

The minimum possible value of the maximum bending moment in the ring girder occurs when $a = 0.04R$ outside the neutral axis. When this is true, the maximum bending moment, M, in the girder is:

$$M = 0.01QR \quad \ldots\ldots\ldots (9.9)$$

The maximum bending stress, f_1 (general bending formula), is:

$$f_1 = \frac{My}{I} \quad \ldots\ldots\ldots (9.10)$$

The maximum ring stress, f_2, due to shear forces is:

$$f_2 = \frac{Q}{4A_r} \quad \ldots\ldots\ldots (9.11)$$

The ring stress, f_3, due to radial forces is:

$$f_3 = \frac{pr}{A_r}\left(C + 1.56\sqrt{rt}\,\frac{A_r - Ct}{A_r + 1.56t\sqrt{rt}}\right) \quad \ldots (9.12)$$

As all of these stresses are combined at the horizontal diameter, the total maximum stress, f, in the ring girder is:

$$f = f_1 + f_2 + f_3 \quad \ldots\ldots\ldots (9.13)$$

The maximum allowable stress in the ring girder or the pipe shell when the pipe is fully loaded is usually 10,000 psi, or 18,000 psi if half loaded.

To support the ring girder, a short column on each side of the pipe is attached to the girder and supported on a pier either by direct bearing or by a roller device, rocker assembly, or pin connection. In any event, the design must permit longitudinal movement of the pipe as well as afford adequate support. Figures 9.3–9.9 and Fig. 9.11 show methods in use.

Some advantages of ring girder support for pipelines are that it permits replacement of flumes, reduces flood and highway hazards, eliminates inverted siphons, avoids expensive substructures required by other types of construction, and affords a practical method of crossing streams, swamps, and marshes. There are a number of useful design references on this subject (*6, 9–13, 15, 16*).

Fig. 9.6. Rocker Support for 66-in. Pipe

The supporting assembly is similar to the roller support shown in Fig. 9.5, except that a rocker has been substituted for the round roller. This permits longitudinal movement of the pipe and prevents uplift and sidewise motion.

9.7.3. Discussion of Design Factors

Equation 9.6 was developed through the analysis of a pipe supported at the ends, acting as a simple beam. It can be shown that, in the case of continuous pipelines, the direct longitudinal stresses can also be derived from the theory of continuous beams.

The direct longitudinal stress f_L from Eq 9.6 for the simple beam condition has to be multiplied by two-thirds to obtain f_L for the continuous-beam condition. Multipliers for unequal spans and other end conditions are proportional to the moment coefficients for those conditions, with due regard given to the position and sign of the maximum moment.

If the pipe ends are fixed, the longitudinal stresses due to temperature change must be added to f_L in Eq 9.6. When expansion joints and bearings of low frictional resistance (see Fig. 9.5–9.7) are provided, however, the temperature stresses may be practically eliminated. Additional thrust or pull due to installation on a slope also must be considered. Data relative to earthquake forces acting on ring girder–supported pipe have been published (*6*).

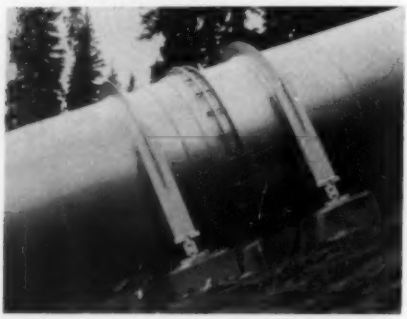

Fig. 9.7. Expansion Joint Between Stiffener Rings

The rings are supporting a 54-in. diameter pipe laid on a slope.

Ring buckling of the pipe shell must be investigated if there is a possibility of outside pressure or partial vacuum. Standpipes or relief valves may prove economical.

Wrinkling due to longitudinal compressive stresses in thin, hollow cylinders has been analyzed theoretically, and specimens have been tested (*7*). The theoretical wrinkling stress was not reached in any test. The wrinkling strength of the cylinders tested varied approximately directly with the t/r ratio up to a certain critical value of this ratio. The critical value was about 0.003 for thin fabricated specimens. For values of t/r equal to or less than 0.015, it was concluded that the full yield strength of the steel (up to 33,000 psi) would be developed before wrinkling occurred.

The critical wrinkling *strain*, ϵ, is given by the expression $\epsilon = (z)0.60\frac{t}{r}$, in which z is an experimentally determined constant. For fabricated specimens with $t = 0.125$, z equals 0.18 to 0.23, and for large fabricated specimens with $t = 0.25$, $z = 0.25$ to 0.26.

The critical wrinkling *stress* may be obtained by direct reading of a tension stress-strain diagram of the steel used, such as Fig. 1.4 (Chap. 1). One authority (*8*) suggests that a conservative value of wrinkling stress be taken as $0.12E\frac{t}{r}$, in which E for steel is 30,000,000.

Table 9.5 has been prepared to show the results of applying the critical wrinkling strain-stress theory of Wilson and Newmark (*7*) and the conservative wrinkling stress expression of Younger (*8*) for values of t/r in actual installations mentioned in Schorer (*3*).

Although not true theoretically, it was found when testing that strength decreased somewhat as length increased, being 20 per cent less for 35-ft lengths than for 6-ft lengths of 34-in. diameter specimens with ¼-in.-thick wall. Irregularities in form which

may occur on a relatively greater scale for the thinner material may account for the higher critical wrinkling stresses found for the thicker material.

The rim bending stress in the pipe shell given by Eq 9.7 reduces rapidly as the point considered moves away from the support, vanishing almost completely at a distance of $4.89\sqrt{tr}$ from the edge of the ring girder (*9*). When reinforcement of the shell is needed at the support, this fact should be noted. The vanishing distance is less than 19 in. for the example given in Sec. 9.7.5.

9.7.4. Pipe Half Full

For design purposes it is convenient to compare the maximum longitudinal stress and radial bending stress in the pipe shell for the half-full condition with the maximum longitudinal beam stress, f_L, for a simply supported full pipe (Eq 9.6; $w = 0$). The corresponding stress ratios designated by n_L and n_r become functions of a pure number, k, defined as:

$$k = \frac{L}{r}\sqrt{\frac{t}{r}}$$

In actual cases, the value of k varies from about 0.20 to 1.20. Within this range:

$$n_L = \frac{1}{\sqrt{k}}; \quad n_r = \frac{0.31}{\sqrt{k}}$$

The half-full condition causes higher stress than the full condition when k is less than unity. The ratio n_L remains the same for continuously supported pipe. The value of f_L (Eq 9.6; $w = 0$) multiplied by n_L gives the maximum longitudinal stress for the half-full condition; likewise, if multiplied by n_r, it gives the maximum radial bending stress in the pipe shell. As the rim bending stress, f_{bo}, from Eq 9.7 is zero in Eq 9.8, relatively high longitudinal stresses may be allowed for the half-full condition. A value of 10,000 psi has been suggested by Cates (*10*) for the full condition and 18,000 psi for the half-full condition.

In the ring girder, the maximum moment for the half-full condition is 3.88 times the moment value for the full pipe when a value of 0.04 for $\frac{a}{R}$ (the value which gives the minimum moment for full condition) is used in design. This is not as serious as may appear at first, because the assumptions leading to the value 3.88 are conservative. Also, several of the forces and conditions present when the pipe is full are not present when it is half full. For these reasons, stresses near the yield point may be allowed for the relatively infrequent conditions of filling and emptying the pipe (*3*). The pipe shell and ring girder should, however, be investigated for the half-full condition. The references should be consulted.

Fig. 9.8. Anchor Block

This block anchors a 66-in. diameter pipe against longitudinal movement.

Design aid coefficients for analyzing stiffener rings for full, partly full, and earthquake forces have been published (*9*). Other useful data have also appeared (*11–15*).

9.7.5. Example of Calculation, Continuous Pipelines

Conditions: $D = 120$ in.; $t = 0.25$ in.; $L = 100$ ft; $C = 1$ in.; $A_r = 1$ in. $\times$ 12.25 in.; $a = 0.04R$; $h = 100$ ft; $w = 12$ psf; $q = 62.5$ lb/cu ft.

Shell stress:

From Eq 9.5, the maximum ring stress:

$$f_r = \frac{D}{2t}(w + qh)$$

$$= \frac{120}{2(0.25)}[12 + 62.5(100)]\left(\frac{1}{144}\right)$$

$$= 10{,}440 \text{ psi}$$

The maximum longitudinal stress (Eq. 9.6) for continuous pipeline:

$$f_L = \frac{L^2}{4t}\left(\frac{2w}{D} + \frac{q}{2}\right)\left(\frac{2}{3}\right)$$

$$= \frac{100^2(12)}{4(0.25)}\left[\frac{2(12)}{10} + \frac{62.5}{2}\right]\left(\frac{2}{3}\right)\left(\frac{1}{144}\right)$$

$$= 18{,}690 \text{ psi}$$

The maximum rim bending stress (Eq 9.7):

$$f_{bo} = \frac{1.82(A_r - Ct)}{A_r + 1.56t\sqrt{rt}}\left(\frac{pr}{t}\right)$$

$$= \frac{1.82[12.25 - 1(0.25)]}{12.25 + 1.56(0.25)\sqrt{60(0.25)}}(10{,}440)$$

$$= 16{,}570 \text{ psi}$$

From Eq 9.8:

$$f = f_L + f_{bo}$$

$$= 18{,}690 + 16{,}570 = 35{,}260 \text{ psi}$$

Fig. 9.9. Ring Girder-Supported Pipe

The pipe shown has a diameter of 14 ft 8 in., with a wall thickness of $\frac{3}{8}$ in.

By changing $L = 100$ ft to $L = 60$ ft, the value of f becomes 23,310 psi, which is still excessive. Consequently, the thickness, t, should be increased adjacent to the support for a 10-ft course, thereby reducing the stress, f, to proper value. By using $\frac{3}{8}$-in. plate, f becomes 14,650 psi, which is satisfactory. Based on $L = 60$ ft, the total reaction transmitted to the supporting ring is $Q = 60(\pi \cdot 10 \cdot 12) + (\pi \cdot 5^2 \cdot 62.5) = 317{,}000$ lb.

Ring stress:

The maximum bending moment in the ring girder (Eq 9.9):

$$M = 0.01QR$$

$$= 0.01(317{,}000)(66.25) = 210{,}000 \text{ in.-lb}$$

From Eq 9.10–9.13:

$$f_1 = \frac{My}{I} = \frac{210{,}000(6)}{12^3} = 8{,}750 \text{ psi}$$

$$f_2 = \frac{Q}{4A_r} = \frac{317{,}000}{4(12.25)} = 6{,}470 \text{ psi}$$

$$f_3 = \frac{pr}{A_r}\left(C + 1.56\sqrt{rt}\,\frac{A_r - Ct}{A_r + 1.56t\sqrt{rt}}\right)$$

$$= \frac{43.4(60)}{12.25}\left(1 + 6.04\,\frac{12}{12.25 + 1.51}\right)$$

$$= 1{,}320 \text{ psi}$$

$$f = f_1 + f_2 + f_3$$

$$= 8{,}750 + 6{,}470 + 1{,}320$$

$$= 16{,}540 \text{ psi}$$

9.8. Ring Girder Construction for Low-Pressure Pipe

General designs for four types of long-span pipe of the flow line variety are shown in Fig. 9.11.

Type 1. Usually recommended for crossing canals and other low places where a single length of pipe for spans up to 60 ft can be used, Type 1 pipe may be made and shipped in one length from the factory or in two lengths; in the latter case, a welded joint must be made in the field at the time of installation.

Type 2. Used in crossing highways, canals, or rivers, where the length of the crossing makes necessary two intermediate supporting columns, Type 2 pipe is designed in three lengths with flanges welded to the ends of each length at points of contraflexure, together with expansion joints for both intake and outlet. This type is normally used for crossings from 60 to 132 ft, with end spans one-half the length of the center span.

Type 3. Type 3 differs from Type 2 in that each end span is 80 per cent of the length of the center span. Type 3, therefore, can be used for longer crossings than Type 2. It requires two expansion joints and five lengths of pipe with flanges welded to ends of each length at points of contraflexure. Type 3 may be used for overall crossing lengths from 104 to 260 ft.

Type 4. Type 4 is designed for conditions where it is necessary to support a continuous series of long, clear spans. The structure may be made in lengths to suit any field condition. Any number of intermediate spans may be used, with as many expansion joints as needed for the overall length of the installation.

9.9. Installation of Ring Girder Spans

In addition to proper design, long-span ring girder–supported steel pipelines require careful field erection, particularly in regard to alignment and camber, avoidance of movement caused by temperature differences on opposite sides of the pipe, and correct welding procedure. The following

suggestions will be helpful, and more information has been published (*15*).

9.9.1. *Concrete footings.* Before assembling the pipe, concrete footings (but not the intake or outlet boxes) should be poured. If the pipe is to be supported on rollers, a pocket is left at the top of the footings as a base for the roller bed plates. If steel bents are to be used, anchor bolts are set in concrete footings for holding the lower end of the pin-ended steel bents or the base plates. The concrete footings should be finished a little low to allow for grouting these supporting members to their proper height.

9.9.2. *Expansion joints.* Expansion joints are installed in long-span steel pipe to allow for expansion or contraction caused by temperature changes. These joints are placed near the concrete headwalls and should be left entirely loose until the concrete has been allowed to set for at least 2 weeks. If expansion joints are tightened before concrete is poured, the pipe may pull loose from the green concrete. After concrete has set thoroughly, expansion joints are tightened and all danger of damage from pipe movement is eliminated.

To protect the expansion joint during shipment, it may be necessary for the manufacturer to tack weld steel ties to the inside of the pipe, tying the two pieces of pipe together across the joint. *When this is done, the steel ties must be knocked loose from the pipe as soon as it is set in place and before concrete is poured.*

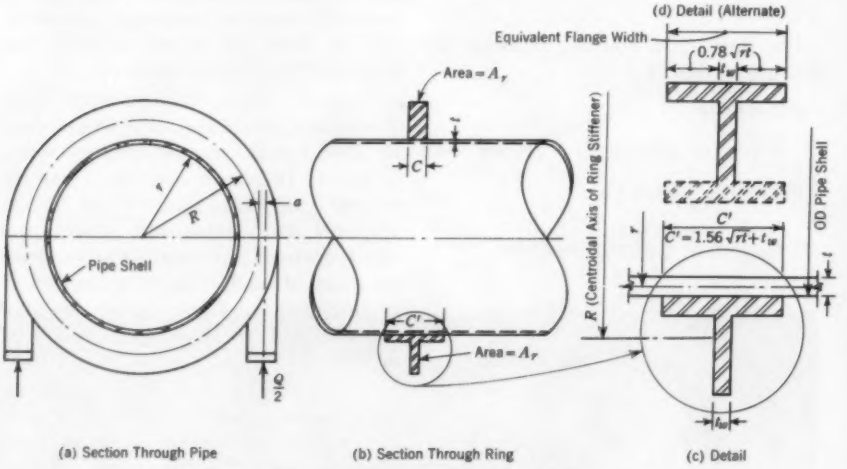

Fig. 9.10. Pipe and Ring Girder Support

See Sec. 9.7 for explanation of symbols.

9.9.3. *Assembling pipe.* Pipe being assembled should be supported by temporary framework between piers. All bolts, except expansion joint bolts, are tightened. When pipe is in place, concrete intake and outlet boxes are poured. Bed plates for the

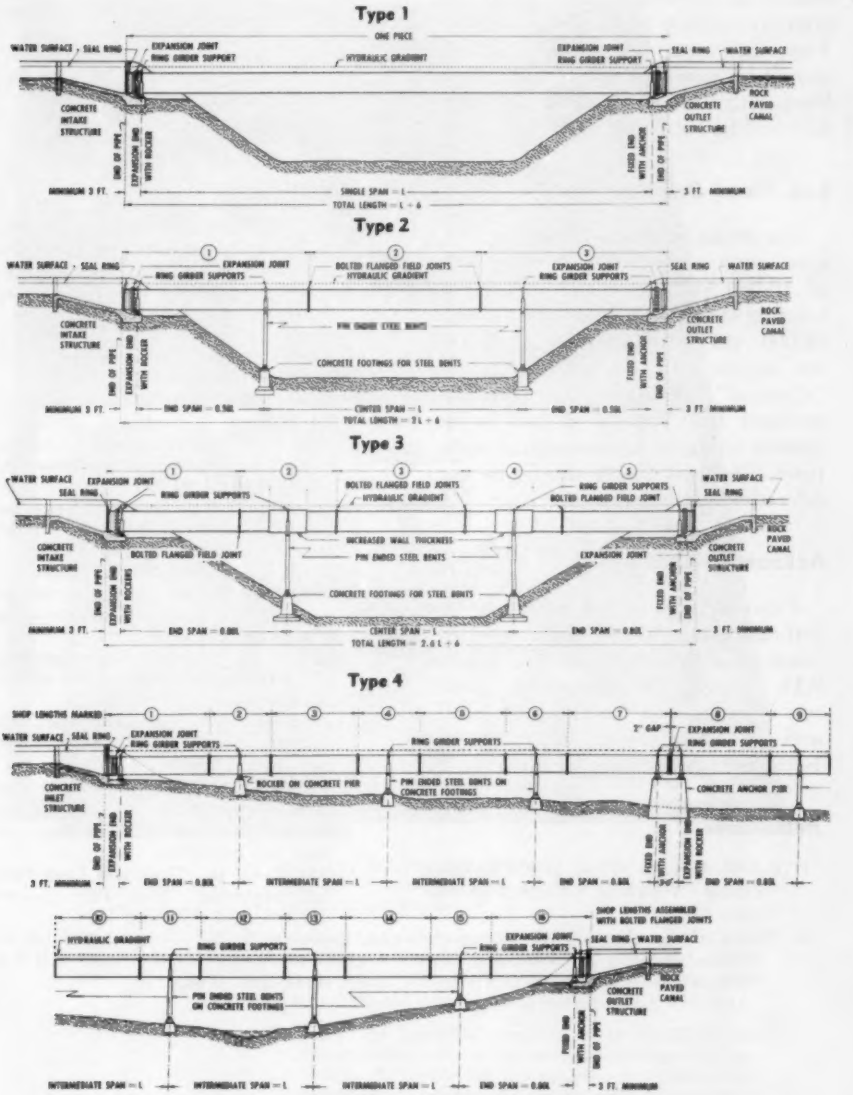

Fig. 9.11. Long-Span Steel Pipe for Low Pressures

See Sec. 9.8 for a discussion of the uses of each type of pipe.

rollers or pin-ended steel bents are grouted in place to the proper height. Temporary supports and blocking should be removed before the pipe is filled with water, otherwise the structure will be subjected to undue stress.

9.10. Good Practice

The *principal* beam stresses in long-span pipe should be on the order of 10,000 psi maximum. *Combined* bending stresses may reasonably reach 18,000 psi. If secondary stresses are mathematically analyzed using "classical" methods, the principles outlined in Chap. 1 should be reviewed to avoid uneconomical structures. Seismic forces should be considered when necessary.

Acknowledgments

Figures 9.2 and 9.4 were supplied through the courtesy of Armco Steel Corp., Middletown, Ohio; Fig. 9.7 and 9.11, through the courtesy of Thompson Pipe & Steel Co., Denver, Colo.; and Fig. 9.9, through the courtesy of Bethlehem Steel Co., Bethlehem, Pa.

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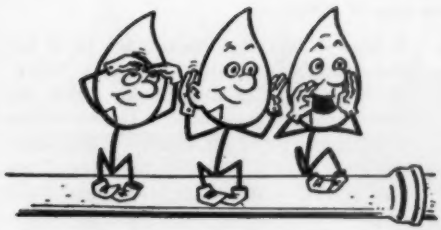

Percolation and Runoff

Drowning is what we are these days, drowning in the salt-water and short-water statistics that are flooding the nation's press. Toward our survival, it seems important that we learn to swim rather than just wish that the flood would end, for, properly channeled, such a flow of information about water could in short order make our public aware and appreciative of our accomplishments and needs. Meanwhile, we can hope to keep afloat by grasping at the occasional straws of accurate reporting and by providing the material out of which those straws can be made.

It is quite impossible these days to keep up with or to keep accurate the inundation of information on water supply. Not only the newspapers and magazines and radio and TV, but investment service scratch sheets, bank bulletins, and almost all other communications media have turned to the task of alerting the public to the imminence of a water shortage that can be warded off only by desalting the sea. That there really is no water shortage seems incidental. Although it is what is that ultimately matters, it seems to be what seems to be that matters most right now.

Thus, from Washington, D.C., on Jul. 18, Scripps-Howard columnist Peter Edson, presumably relying on some better source than his own observation, reported:

> In 1900 the United States used about 40 bgd of fresh water. Last year it was over 300 bgd. By 1970 use is estimated at 400 bgd; by 1975, 450 bgd. There just isn't that much fresh water available.

Quite obviously it wasn't the USGS that provided the figures, for they report present consumptive use at 61 bgd and cite 597 bgd as the amount that can be made economically available. It wasn't Abel Wolman, chairman of sanitary engineering and environmental control for the National Research Council, who indicates that actual consumption in 1980 will be on the order of 120 bgd. And it wasn't the Senate Select Committee on National Water Resources, which reported:

> Projected consumptive uses of water diverted from streams or underground sources thus range from an amount less than 10 per cent of streamflow in 1954 to 11 per cent in 1980 and about 14 per cent in the year 2000.

Who it was doesn't really matter too much. There are plenty more where he came from. And the widespread dissemination of such "knowledge" is helping to assure a more or less crash

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program of desalinization research, the success of which will certainly be important in giving the water utility field another string to its bow. The fact is, though, its present string is only about 10 per cent used, and it is mighty short of arrows. Just a couple hundred billion of those crash dollars could provide a lot of badly needed fresh-water source, treatment, and distribution facilities.

We're sometimes tempted to turn over on our backs and float, waiting for the day when, with the whole ocean available, the continued need for sprinkling restrictions will finally prove our point. But for fear we won't live that long, we're starting to dog paddle now. And if the first stroke—this item by Frank C. Porter in the Sunday Washington *Post* of Jul. 23:

A trade group has thrown cold water on the current excitement—shared by President Kennedy and stock speculators among others—for desalting the sea.

The American Water Works Association, which has more than a passing interest in the status quo of tapwater, claims that on the basis of valid comparisons, the cheapest desalinized product is 20 times as expensive as fully treated fresh water.

The rub comes, says the Association, when desalting enthusiasts try to compare merely the cost of running a desalinization plant alone with the full costs of fresh water, including treatment, distribution, depreciation and administrative costs.

The average cost of fresh water to public suppliers is 12.3 cents per 1,000 gal, all factors included, the Association continues. The actual cost of fresh water treatment is only about 5 cents per 1,000 gal compared to $1 for the desalting process at the new Freeport, Tex., plant.

The Association claims it is not trying to talk down the desalinization program; it says it sees real importance in it for the nation's future and for many water-short areas of the world today. But, the trade group argues, in the United States total consumption of water "at the present time is only about 10 per cent of the total fresh-water supply economically available," thus leaving an adequate margin for some time to come.

wasn't classy, it did splash a few facts around.

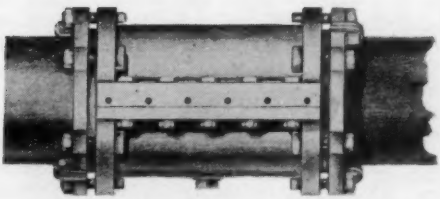
With cost and price thus properly differentiated, it may be helpful to give some examples of imaginative rate schedules. And we are thinking of nothing so picayune as the $1.25 per 1,000 gal rate reported for a community in the vicinity of Washington, D.C.

Down in Houston, Tex., four men were successful in selling water at approximately $1,500 per 1,000 gal—not through the tap, of course, but packed in containers labeled "Meadowgold" and "Vita-Pakt" together with some sugar and orange juice. The men, officers of Cal-Tex Citrus Juices, Inc., were convicted last May, not because of the price charged for the water, but for the fact that they labeled the container "pure orange juice."

Then, in Trumansburg, N.Y., a grocer thought he would try his hand at merchandising our product, canned, as "Instant Water—best possible way to make coffee, particularly instant coffee" and "fine for outdoor cooking." He had no trouble at all in getting rid of five quart cans at 85 cents per can or $3,400 per 1,000 gal. And the fact that he refunded the money next day did not unprove his point.

Meanwhile, as reported in June (P&R p. 96), a Department of Agriculture order has made it quite legal for butchers to sell water, injected into

(Continued on page 40 P&R)



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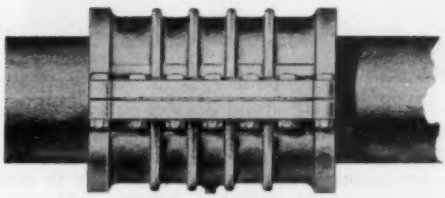

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(Continued from page 38 P&R)

hams up to a total of 10 per cent of weight, at a price of more than $5,000 per 1,000 gal. And Sen. Maurine Neuberger of Oregon has figured that, in this form, butchers each year will sell $87,500,000 worth of "federally inspected water."

But the real touch of genius has been shown by a number of different entrepreneurs who have made unconverted sea water their stock in trade, selling it unadulterated and untreated at rates up to $20,000 per 1,000 gal as a "fountain of youth" drink that is also effective as a cure for arthritis, cancer, diabetes, multiple sclerosis, Parkinson's disease, and leukemia. Seized by the Food & Drug Administration in Salina, Kan., were a supply of half-pint bottles of "Sea Brine Concentrated Natural Sea Water" bottled at Lakeland, Fla., by the Florida Sea Brine Laboratories, Inc. Meanwhile, in Ohio, 93 gal of an unbranded, cut-rate sea water bottled near Belmar, N.J., was seized by the FDA, and in Lansing, Mich., the state food and standards division seized a supply of similar stuff, selling at $1.69 per pint.

What the public water supply field needs is imagination!

Fluoridation causes high blood pressure, it seems, whenever it is subjected to public debate. And in this stage, too, some major mottling results, as the cheeks of both proponents and opponents often turn almost purple with frustration or fulmination. We can imagine that some heat prostration must occur as well when the issue is introduced in mid-July as it was this year in Kansas City, Mo. But as yet there has been no proof of ill effects after adoption.

At KC, the decision had not been rendered when this report went to press, but the situation was characteristically hypertense. Things were no more genteel last April either, when well-mannered Wellesley, Mass., along with Brookline and Andover, was similarly afflicted and voted not to take their doctors' and dentists' advice.

Said Dr. Frederick B. Exner, Seattle radiologist who has stumped the nation to fight fluoridation, at a public hearing in KC:

> It isn't sensible to put any drug in the water supply. . . . No benefit has been proved. When they say that the benefit of fluoridation has been proved, it is an outright lie. . . .
>
> No government has the right to decide what drugs I must take as long as I pose no threat to public health. It is a precedent for substituting a completely totalitarian government in place of the constitutional republic we have enjoyed.

Said Dr. Frederick J. Stare, Harvard nutritionist and Wellesley fluoridation proponent, at an AMA meeting where he urged doctors to support and encourage fluoridation:

> But to do this, you will have to stand up to personal abuse from an odd assortment of food nuts, organic gardeners, John Birchers, pure water enthusiasts, and others whose comic chemistry transcends common sense.
>
> These self-righteous pseudoscientists, who think they have such a complete understanding of the second most prevalent disease of mankind, deny over half of our children and over 100,000,000 Americans of the next generation the opportunity to have only half the tooth decay you have.

Said *Time* magazine, in reporting the Wellesley referendum:

(Continued on page 42 P&R)

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(Continued from page 40 P&R)

The reason [that fluoridation fails to win on referendums] is that psychologically the issue lends itself to the purposes of otherwise insignificant political fringe groups. Playing on the populace's anxieties, they can get on a winning side and look more influential than they are.

So F continues to mean "fight."

An F fight on another front is about to begin, too, as Bristol-Myers Co. has brought out its Ipana toothpaste in a new form, containing sodium fluoride, to challenge Procter & Gamble's stannous fluoride Crest. In its new and more so form, the "smile of health" dentifrice is said to possess "more decay-germ killing power than any other leading brand." It now remains to be seen whether the American Dental Association, which gave recognition to the caries-preventive value of Crest, will be asked to, and if asked will, give similar recognition to Ipana.

What with fluoride dentifrices, toothbrushes, chewing gum, and beer already invented, we are going to have to concentrate on our sodium silicofluoride nail polish "for girls who bite their nails."

Robert B. Diemer is retiring as general manager and chief engineer of the Metropolitan Water District of Southern California, after 32 years of service with the organization. He has been general manager since January 1952.

(Continued on page 44 P&R)

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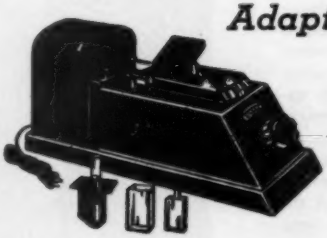

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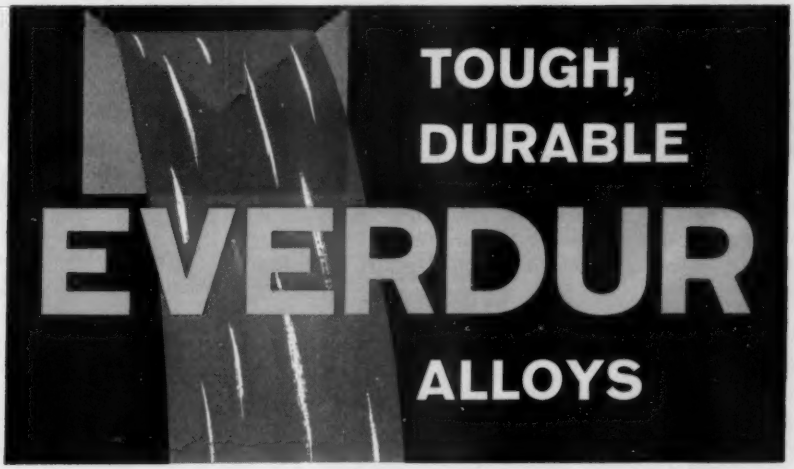

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(Continued from page 42 P&R)

Fire Prevention Week, Oct. 8–14, is a week in which water supply will be feted, too, as the backstop of prevention. The more prevention, we might point out, the less free water you must supply for extinguishing fires. And the better the water system, you might point out, the lower the fire insurance rates and the less the fire damage.

Speaking of extinguishment, though, recalls a recent demonstration by the New York City Fire Department of a new "ultra-high expansion foam extinguishing system." The demonstration took place in an old three-story building on Welfare Island where firemen started a blaze on the first story and then went to work on it promptly with the new goo. In no time at all the whole building was in flames, requiring thousands of gallons of a ne plus ultra extinguishing system to do the job. Be it ever so humble, it's no place for foam.

Pool's gold is what the Atlanta, Ga., water department is collecting these days as a result of a special service set up for the city's 1,000–1,400 private pool owners. At a price of $60–$70 per pool, Paul Weir's men go to work with hoses hooked up to nearby fire hydrants and do the filling job in 4–5 hr instead of the days required through a garden hose hooked up to the sill cock. Service on tap, of course, says Paul, but we plug our service too!

(Continued on page 48 P&R)

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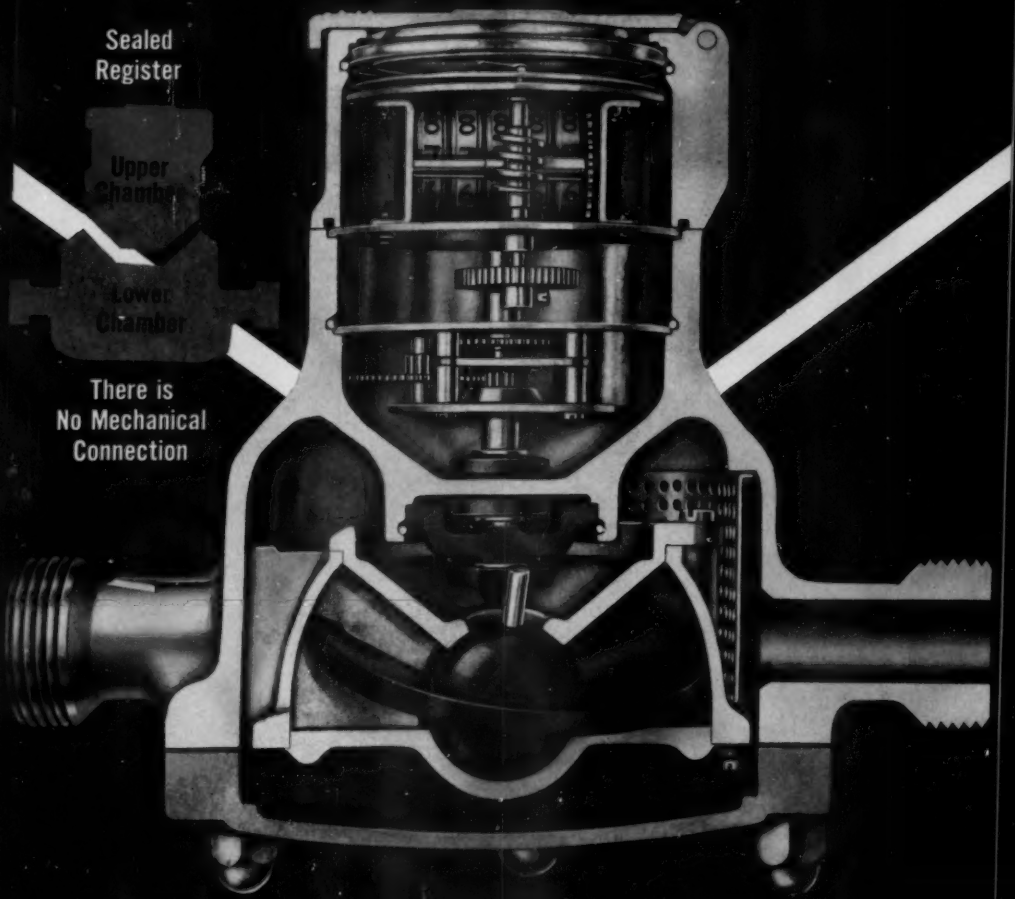

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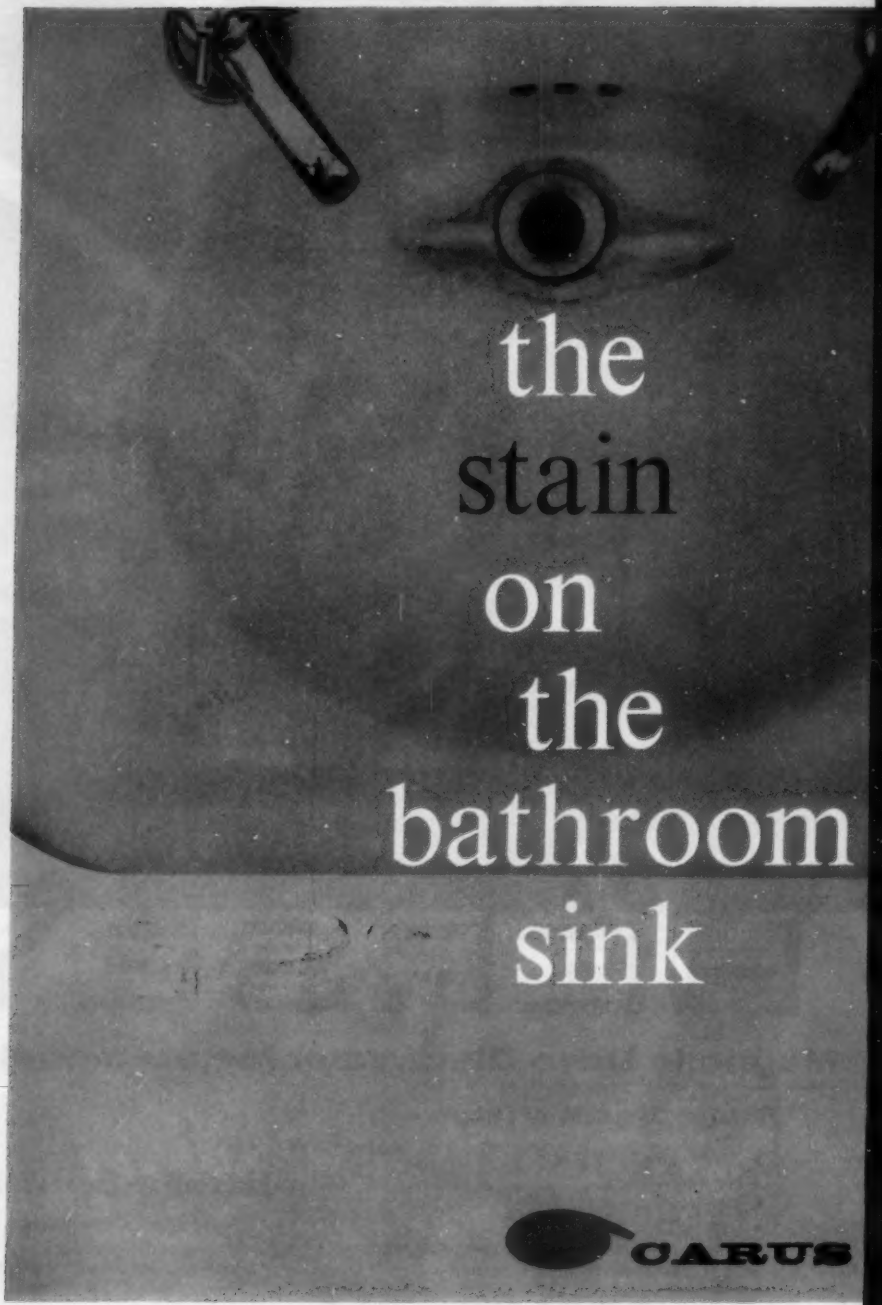
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CHEMICAL COMPANY, INC

(*Continued from page 44 P&R*)

Thomas E. Drumm Jr. has been appointed administrator of the Business and Defense Services Administration, US Department of Commerce. He has served as assistant administrator since September 1958 and has been acting administrator since March 1961.

Seymour Zubkoff, a principal engineer on the staff of the Hydrotechnic Corporation, hydraulic and sanitary engineers of New York City, has been assigned to Saigon, Viet Nam, in connection with the firm's engineering work for the new Saigon-Cholon Metropolitan Water Supply project.

(*Continued on page 50 P&R*)

This Month Years Ago

September 1911—An appropriation of somewhat more than $8,000,000 was made for the construction of a water filtration plant at the eastern basin of the Jerome Park Reservoir in New York City. "Preliminary work will consist of bringing up to date the plans and specifications originally prepared for (slow) sand filtration and preparing also complete plans and specifications for a mechanical filtration plant, with the object of comparing the two methods."

"The matter of waterproofing a standpipe to prevent absorption is well developed at present. The one disadvantage with the patented waterproofing compounds is the high cost. 'Sylvester's Solution,' castile soap and alum, will give lasting and perfectly satisfactory results."

"Some of those who are trying to aid in the much-needed campaign for water-waste reduction are advocating that the Commissioner of Water Supply shall have the power to establish 'standards of size, weight, and quality of all new fittings which shall hereafter be used for the distribution of water in or outside of buildings.' Power of this kind should certainly be given to the city authorities of New York, particularly if it is to remain a practically unmetered city."

Gas in a well near Kenwood, Pa., caused the death of two men. One of the men was asphyxiated while installing the pump in the completed well, which was about 25 ft deep, and the second was overcome while attempting to rescue his fellow workman. The two bodies were recovered by a man who was let down into the well with one end of a garden hose held in his mouth to supply him with fresh air from above.

"Every year now a good many towns of about 1,000 population are for the first time installing public water supplies. More and more a public water supply is coming to be regarded as a necessity rather than a luxury. This attitude on the part of the citizens of small cities is now becoming so common that a number of very good engineers are devoting all, or a large part of their time to designing and supervising the construction of water works in small municipalities."

At Lawrenceville, Ga., the citizens voted Aug. 23 to issue $35,000 for the construction of water works. At Biloxi, Miss., "bids will be received until Sep. 15 for $70,000 in water works bonds." At Marysville, Mo., the citizens on Aug. 24 voted to issue $100,000 in bonds, with which to purchase the present water plant and improve same. At Jersey City, N.J., "the Board of Finance will receive bids Sep. 22 for $7,000,000 bonds, proceeds to be used to purchase the Boonton water works." At Manitowoc, Wis., the citizens voted to issue $230,000 in bonds, with which to purchase the plant of Manitowoc Water Co.

"I ended up with 'do-it-myself' service...

. . . did I get taken! I plead for pump service — and find out I'm talking to the salesman's telephone answering service. 'He's out in the territory,' they tell me . . . 'won't be back until Friday.' *Territory,* indeed! What am I supposed to do, organize a bucket brigade until Friday? Why can't that manufacturer hire someone to *service* pumps! Someone who fixes 'em for a living — not a salesman who just does service as a sideline."

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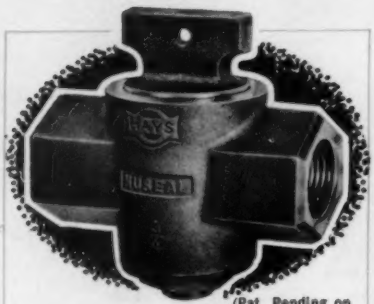

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(*Continued from page 48 P&R*)

Compact Gets by Roadblock was the story as the Delaware River Basin Compact finally received the endorsement of Interior Secretary Udall after a review of the constitutionality of federal participation in the compact on an equal basis with the four states involved. Having received confirmation by the legislatures of Delaware, New Jersey, and New York already, the compact now needs official approval by the Pennsylvania legislature and by Congress, but it is estimated that land acquisition on the project can get under way in 4 years, if, that is, Washington doesn't again cross up the Delaware!

July in New York was HOT! So hot, in fact, that even the New York *Times* succumbed and printed a two-column photo of a child hanging over a public drinking water fountain on its front page. So hot, in fact, that the police department was forced to issue combat helmets to its patrolmen to protect them from the bricks and other missiles thrown at them by overheated brats when they shut off hydrants being used as public showers. So hot, in fact, that the public may even have been momentarily conscious of the comfort that water provides.

A perspiration inspiration might be: strike while the city is hot to get what you want to give your customers what they want!

Francis R. Hall has joined the New Mexico Institute of Mining and Technology, at Socorro, as an associate hydrologist and faculty associate. He was formerly on the staff of the Stanford Research Institute, Menlo Park, Calif.

(*Continued on page 54 P&R*)

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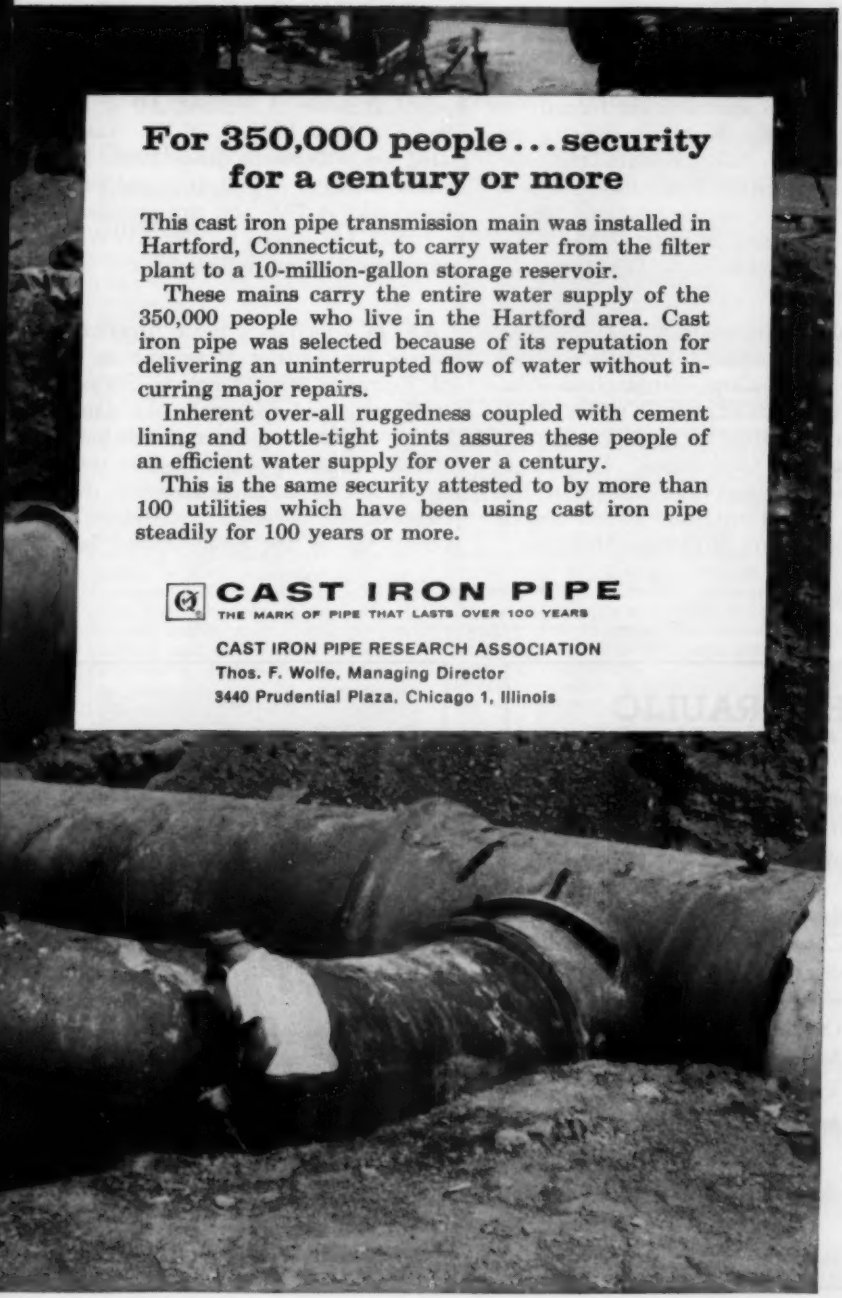

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(Continued from page 50 P&R)

Wistful thinking must have motivated the San Diego Water Department to send workmen out recently to repair its "No Fishing" sign on the bridge over Lake Hodges reservoir east of the city. There hasn't been a drop of water in the reservoir for 10 years or more. In water works, however, 10 years from today is now.

Golden-Anderson Valve Specialty Co. has purchased Rotary Valve & Engineering Corp., Birmingham, Ala., manufacturers of circular rotary valves and linear valves for high-pressure and high-velocity applications. The name of the company has been changed to Rotary Valve Corp., and it will operate as a subsidiary of Golden-Anderson.

Daniel J. Saunders, former vice-president of The Permutit Co., has opened an office as a consultant at 70 Pine St., New York 5, N.Y. Associated with Permutit since 1920, he became manager of industrial and municipal sales in 1936 and vice-president in 1946. He served on the AWWA board of directors in 1949–52.

ASTM, which once meant American Society for Testing Materials, as of Jul. 1 came to mean American Society for Testing and Materials, the name change emphasizing the organization's interest in materials as well as in testing them. The importance of this phase of the society's activities was pointed up by the establishment last

(Continued on page 80 P&R)

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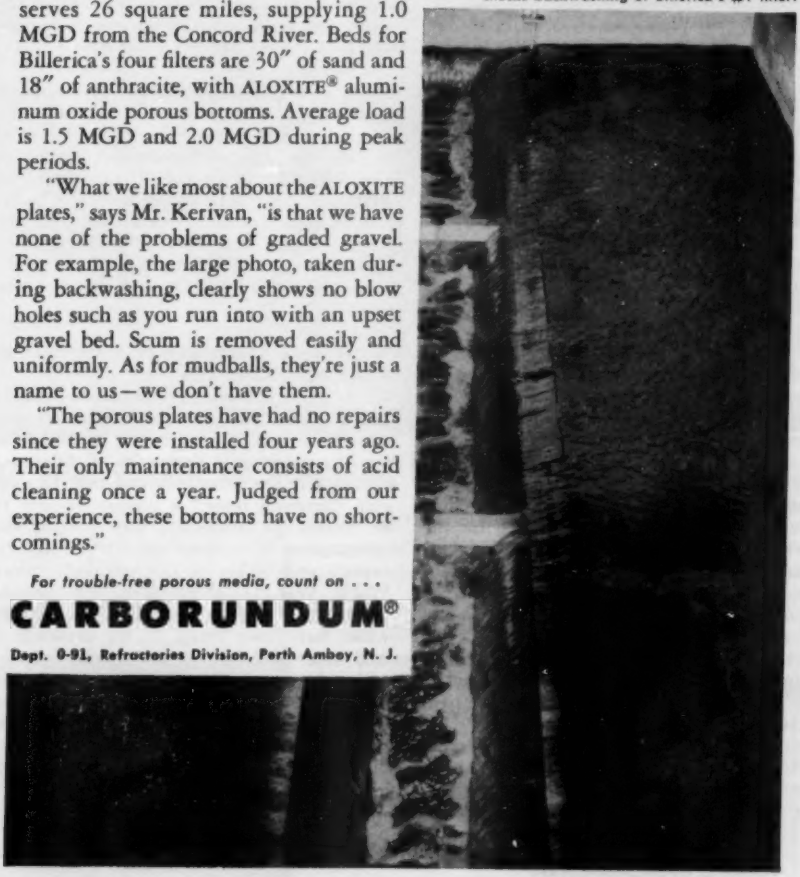


Condensation

Key: In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); NSA—Nuclear Science Abstracts; PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

BACTERIOLOGY

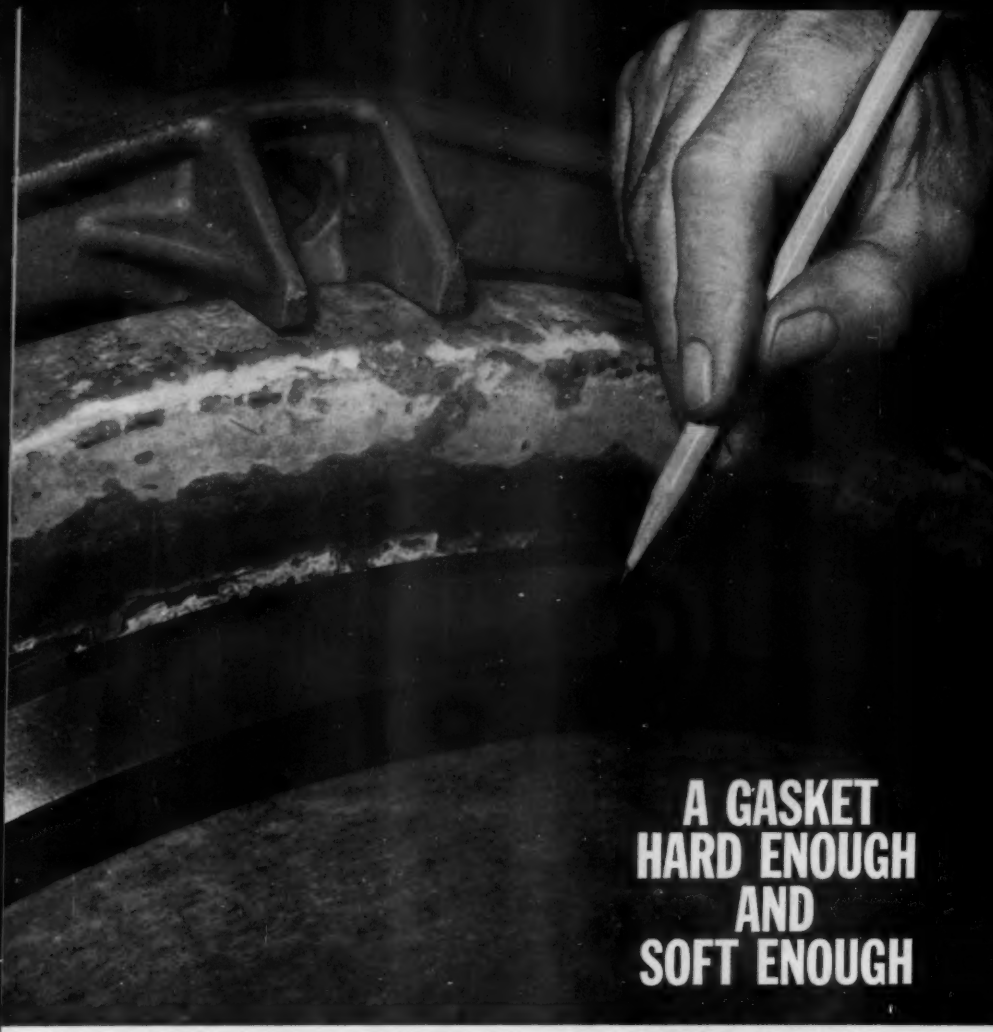
Denitrification in Water and Soils of Lake Sevan. M. E. GAMBARYAN. *Mikrobiol. Sbornik, Akad. Nauk Armyan. S.S.R.*, No. 9, 259 ('58). The microbiol. studies which were made at the Sevan Hydrobiological Station were devoted to detg. the species compn. and the quant. development of denitrifiers. The qual. compn. consists of the following species: *Pseudomonas aeruginosa* and *P. denitrificans*. The quantity of the bacteria in the water of Lake Sevan attains up to 100 cells/ml and, in the bottom deposits, up to 10,000 cells/g of wet deposit. The no. is greatest in the spring and fall. The biochem. processes of reducing the mineral N in the water and in the deposits of Lake Sevan are observed in the spring and in the fall during the period when the accumulation of denitrification bacteria, of readily assimilated org. substances, and of nitrates takes place and when there is a min. in the concn. of free, dissolved O. This accounts for the low concn. and the absence of mineral N in the water of the lake.—*CA*

Production of Antibacterial Substances by Benthic Tropical Marine Algae. M. B. ALLEN & E. Y. DAWSON. *J. Bacteriol.*, 79: 459 ('60). Recent studies have shown that planktonic marine algae may produce antibiotic substances, which would acct. for the bactericidal activity of sea water. Investigations were, therefore, carried out on a number of benthic tropical marine algae collected along the west coast of Central America and Mexico during March and April 1959. The algae were collected and immediately frozen, before transport to the lab. After thawing, the algae were placed in cups on nutrient agar plates that had been inoculated with representative bacteria, and inhibitory zones developed. The antibact. substances were extracted with methyl alcohol and water; the methanol was evapd. and the resulting aqueous solutions were tested for bactericidal activity. Results are presented in a table and show that there is a wide distribution of materials which inhibit the growth of Gram-positive bacteria, whereas Gram-negative bacteria, such as coliform organisms, are unaffected. The results also indicate that there are at least 4 different bactericidal substances in the algae studied. Studies on the concn. and purification of the inhibitory materials are being continued.—*WPA*

Study of a Population of Sulfur-Reducing Bacteria. R. DESROCHERS & V. FREDETTE. *Can. J. Microbiol.*, 6:349 ('60). In addn. to detg. the pop. of S-reducing bacteria in a section of the Ottawa River, detns. of BOD and dissolved O were made. The effect of addn. of sulfite-waste liquor to the river and the amt. of H_2S produced were also studied. Bact. counts reached 1×10^6/ml when the BOD was 220 and the dissolved O nil.—*CA*

Waterborne Outbreaks of Tularemia in Moscow Oblast. M. I. TSAREVA. *J. Microbiol., Epidemiol. & Immunobiol.*, 30:34 ('59). Until comparatively recent years, there have been few references in the literature to waterborne outbreaks of tularemia although it has been indicated that Norwegian "lemming fever," a disease thought to be related to tularemia, was due to the consumption of drinking water pold. with the excreta and bodies of the lemming. Since World War II, there have been several outbreaks of tularemia in the Moscow area which have been traced to the drinking of well water pold. by domestic rodents infected with tularemia. The contamn. of such still waters has resulted in heavy infections among those at risk. Moving stream water may be similarly contamnd., but usually the concn. of *Brucella tularensis* in these waters is significantly lighter, and resulting infections in man are less serious. Several of the out-

(*Continued on page 66 P&R*)



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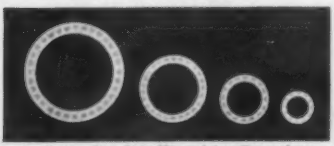

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(*Continued from page 64 P&R*)

breaks have been fully investigated; *Br. tularensis* has been isolated from the dead rodents in the water and also from the water itself. In the opinion of the author, mass vaccination of the pop. at risk offers a very high degree of protection and is probably the most satisfactory method of dealing with the problem. The live tularemia vaccine is widely used in the USSR. In spite of the fact that the virulence of *Br. tularensis* isolated in the USSR is much lower than the strains isolated in the US, the infectivity of the strains seems to be of a high order.—*BH*

Bactericidal Effect of Chlorine in Sea Water and Fresh Water. N. N. ALFIMOV & P. N. YAGOVOI. *Gigiena i Sanit.* (Moscow), 25:85 ('60). Cl is even more effective in disinfecting sea water than fresh water. —*CA*

A Study of Coliform Densities and *Escherichia coli* Serotypes in Two Mountain Streams. N. J. PETERSEN & J. R. BORING. *Am. J. Hyg.*, 71:134 ('60). According to the authors, "it is not uncommon for small communities in the Rocky Mountain area to use untreated water from small, semi-isolated mountain streams as a public water supply." As these waters often give positive coliform tests, a study was made of 2 of these streams. A detailed report is made of the adopted methods of survey, sampling, and bacteriologic investigation. Two figures give diagrams of the areas studied. Tables with description set out the coliform densities and the *Esch. coli* types found at the various sampling points in the 2 areas. It is stated in the discussion that the magnitude of the study "was considerably less than desirable" but that its results may be of use to other studies. Points in the summary are: "Drainage from flood irrigation and the presence of cattle in a stream were found to affect the otherwise uniform coliform densities. The frequent occurrence of the same sero-types at various stations on the same day and on various days at the same station adds knowledge to the questions concerning source and survival of coliform organisms."—*BH*

Bactericidal Action of Various Forms of Residual Chlorine in Water. P. N. YAGOVOI. *Gigiena i Sanit.* (Moscow), 26:103 ('61). Free Cl is 100 times more effective than chloramine Cl in killing bacteria.

(*Continued on page 70 P&R*)

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(Continued from page 66 P&R)

NH_2Cl is somewhat more effective than $NHCl_2$.—*CA*

A Comparative Study of Media for Detection of Enterococci in Water. C. C. CROFT. *Am. J. Public Health*, 49:1379 ('59). Under the sponsorship of the Standard Methods Committee of the Am. Public Health Assn., 8 labs. participated in an evaluation of media for the recovery of enterococci in water. The media studied were Rothe's azide dextrose broth (AD), Hajna's buffered azide glycerol glucose broth (BAGG), and Slanetz and Bartley's M enterococcus agar. Positive results with these media were confirmed by use of the ethyl violet azide dextrose broth developed by Litsky, Mallmann, and Fifield. Parallel studies on coliforms were also made. A total of 185 samples were analyzed with the following conclusions: (1) AD broth and M enterococcus agar gave roughly the same results, BAGG broth gave significantly lower enterococcus counts; (2) median ratios of enterococci to coliforms were calcd. for flowing water, impounded water, wells, and sewage. The ratios were, respectively, 5:1, 4:1, 2.5:1, and 10:1; and (3) enterococcus detns. in water should provide valuable supplementary data concerning poln.—*PHEA*

Microbiological Processes of Hydrogen Sulfide Formation in Lake Solenoe. I. M. V. IVANOV & L. S. TEREBKOVA. *Mikrobiologiya* (Moscow), 28:251 ('59). Formation of H_2S in Lake Solenoe occurs mainly in bottom muds, and rate decreases with depth in the mud layer. Production is slow in littoral muds; at water depths to 5 m the rate approx. doubles, reaching (in winter) 1–1.4 mg/l H_2S of bottom mud per day. Putrefactive bacteria have little or no share in H_2S formation; sulfate reducers are responsible, with cell counts up to 10,000/liter of raw mud and production (in mg/l/day) about 3 in deep water, and commonly about 5 in shallow water. The observed peak is 19 mg H_2S.—*CA*

Observations on the Microbial Flora of the Thermal Waters of Viterbo With Re-

(Continued on page 72 P&R)

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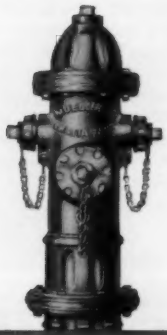

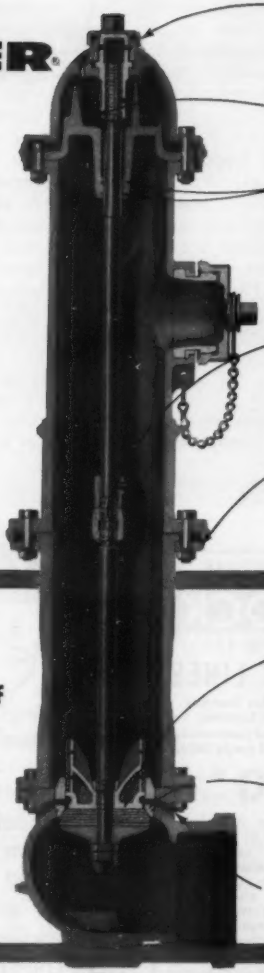

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(Continued from page 70 P&R)

spect to Sulfobacteria. S. ALBERTI; A. TONOLO; & G. D. FELIP. *R.C. Ist. sup Sanit.* (Italian), 22:1018 ('59). Investigations on the microbial flora of the sulfur waters of Viterbo, Italy, have so far led to the identification of a strain of *Rhodopseudomonas palustris.* The morphologic and physiologic characteristics of this bacterium are considered.—*WPA*

Bacteriostasis by Silver and Copper in Pool Water. O. ISHIZAKA ET AL. *Nagoya Shiritsu Daigaku Yakugakubu Kiyo* (Japan), 8:22 ('60). Ag, Cu, and their compds. were studied for their oligodynamic action in pool water. The bacteriostatic effect is caused neither by the metal nor metallic ions but by their higher order oxides. Cupric oxide is excessively bacteriostatic when used alone, but it decomps. easily on chlorination in the pool water.—*CA*

Investigation of the Antagonism Between *E. coli* and *E. freundii* in the Bacteriological Examination of Drinking Water. H. HABS & U. LANGELOH. *Arch. Hyg. u. Backteriol.* (Munich), 144:277 ('60). Strains of *Esch. coli* and *E. freundii* were inoculated simultaneously into a glucose medium. Incubation at 37°C resulted usually in a preponderance of *E. coli,* even when these organisms had been in the minority in the original inoculum. The antagonistic activity depended on the strength of the strain, thus the weakest of the *E. coli* strains examd. was overgrown by the most active of the *E. freundii* strains. These findings are discussed, and the authors conclude that it is unlikely that a universal enrichment method will be found which will fulfill the requirement of being selective for *E. coli* when these are sparsely present among other coliform bacteria and at the same time allow a good growth of coliforms when *E. coli* is absent. It is therefore considered important in the examn. of samples of drinking water to set up 2 batches of sugar cultures and to incubate one at 45°C and the other at 37°C.—*BH*

(Continued on page 74 P&R)

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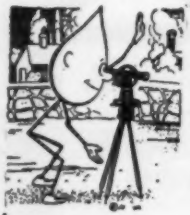

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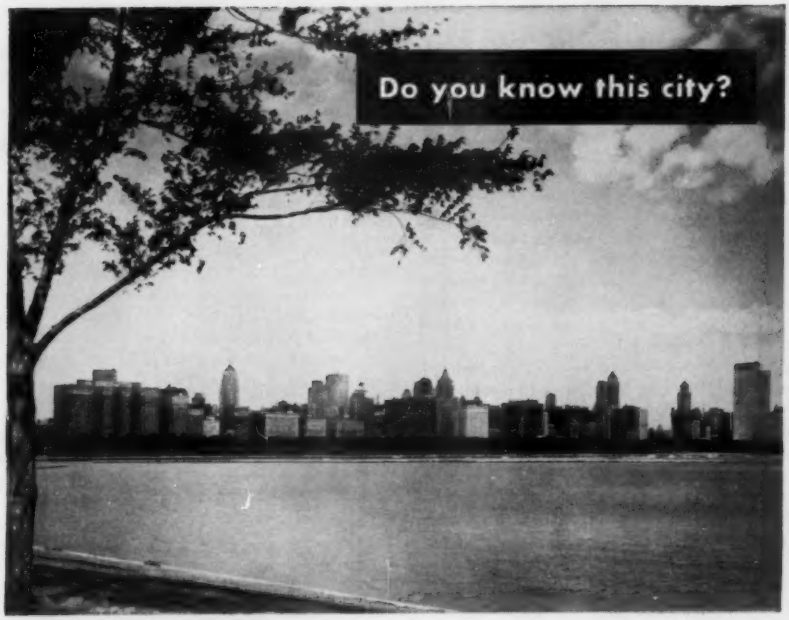

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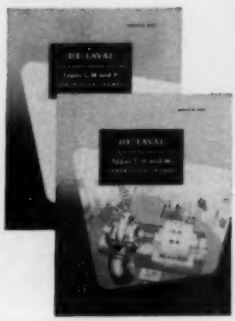

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BL414A

(Continued from page 72 P&R)

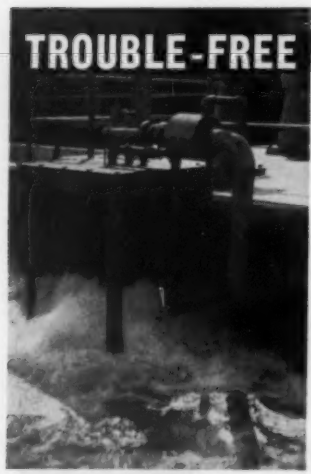
TREATMENT—GENERAL

An Indirect Process for Ozone Treatment of Water and Its Apparatus and Physical-Chemical Principles. G. Axt. *Vom Wasser,* 25:93 ('58). The reaction of ozone with water and the difficulties in its use for the treatment of water are described. Methods adopted to overcome the 3 main difficulties—lack of stability, slight solubility in water, and the necessary presence of other gases—are discussed. The advantages of oxygen over air in prepn. of ozone are considerable, and the author describes a closed system for producing a concd. soln. of ozone in part of the water to be treated and returning this to the main flow without loss of ozone. In dissolving the ozone in the water, a countercurrent absorption column has the advantages over simple mixing in that a higher ozone concn. in the water can be obtained and that more ozone and less oxygen is dissolved in the water. The principles and costs of the process are discussed, and a description, with diagrams, is given of the various parts of the plant required for the process of indirect treatment.—*WPA*

Ozonation of the Lake Constance Water Supply for the City of St. Gall (Switz.). E. Hofmann. *Eau,* 45:119 ('58). Raw water in the winter contained an avg of 5–20 γ/l phenol, with a max. of 80 γ/l. Tests showed that 25 γ/l were sufficient to produce a chlorphenol taste and odor after chlorination. Ammoniation, in addn. to chlorination, did not solve the problem. Tests established that 1 g/cu m O_3 was necessary, after rapid filtration, to yield an effluent of satisfactory bact. qual.—*CA*

The Problem of the Use of Chlorine Dioxide in the Treatment of Water Supplies and Waste Waters. W. Misniakievicz. *Chem. Zentr.* (Berlin), 129:8157 ('58). Chlorine dioxide is suitable for the treatment of water containing phenol. If the

(Continued on page 76 P&R)



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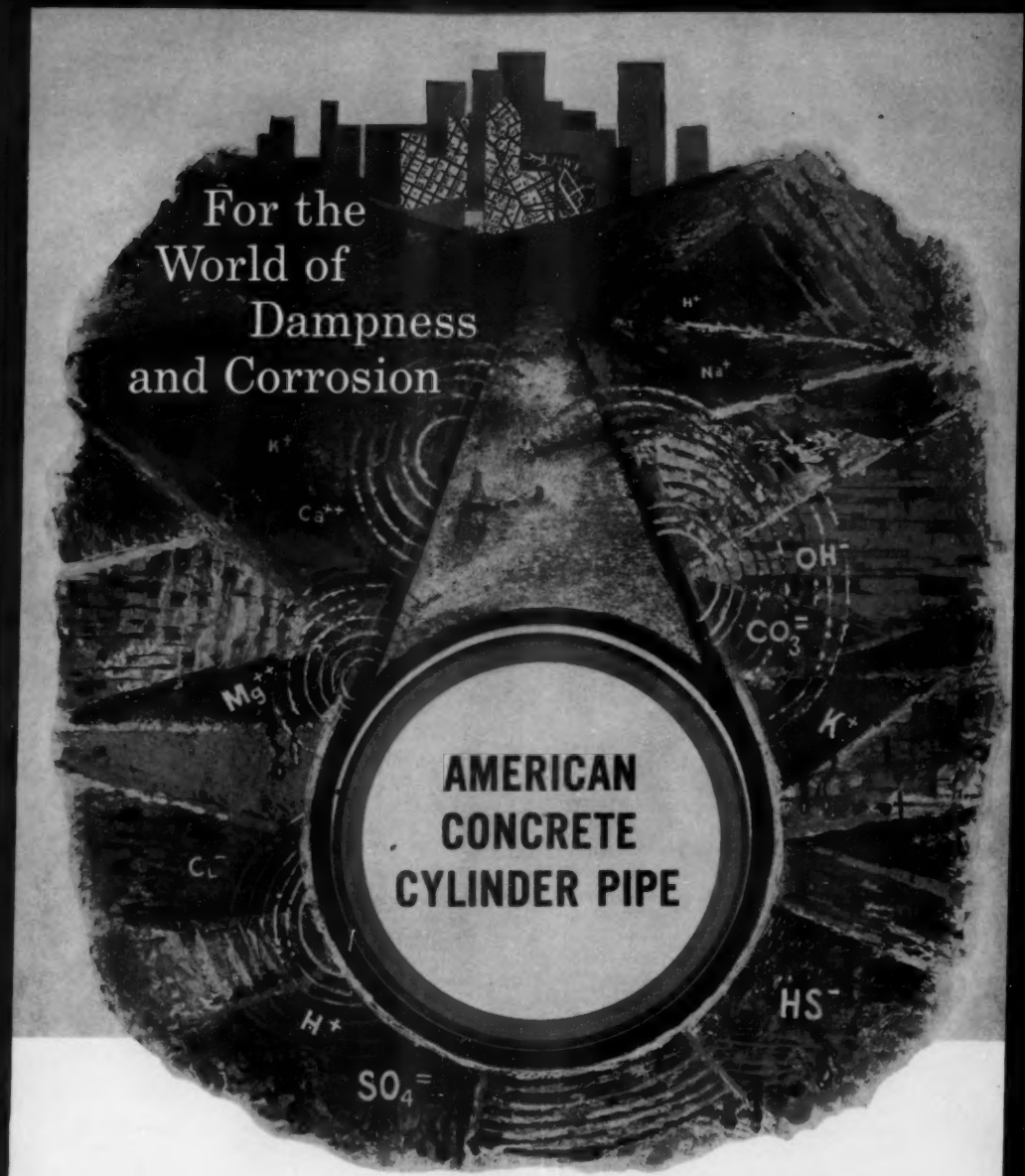

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(Continued from page 74 P&R)

concn. of phenol is greater than 30 mg/l, treatment with chlorine dioxide is uneconomical.—*WPA*

Water Treatment From the Viewpoint of the Water Supply of Chemical Factories. W. CHRIST. *Chem. Tech.* (Berlin), 12:662 ('60). Increased water requirements in the chem. industry have brought about utilization of surface waters. Recent advances in treatment methods are discussed from the standpoint of process requirements.—*CA*

The Importance of Laboratory Research in Designing Plants for Water Treatment by Coagulation. L. ROTT. *Hidrotehnica* (Bucharest), 5:316 ('60). Some basic principles are given for tests (optimum pH, corrosivity, and others) necessary for designing coagulation installations for potable-water plants.—*CA*

Aeration in Tower-Type Fermenters. D. MURPHY; D. S. CLARK; & C. P. LENTZ. *Can. J. Chem. Eng.*, 37:157 ('59). Using the sodium sulfite oxidation method, the effects of rate of air flow, partial pressure of oxygen, size and porosity of aeration disc, height of liquid, and presence of surface-active agents on aeration were studied in 2 unstirred towers or column-type vessels of different diameters. The coefficient of oxygen transfer was found to increase with the rate of flow of air up to the "flooding" point. The rate of air flow required to cause "flooding" was increased by increasing the area of the aeration disc relative to the cross-sectional area of the tower. Within certain limits, aeration was improved by using discs of finer porosity. Under most conditions the coefficient of oxygen transfer was much higher in the small tower. The transfer coefficient was not affected by the height of the liquid in the tower, but efficiency of absorption increased with height. All the surface-active agents tested had an adverse effect on aeration.—*WPA*

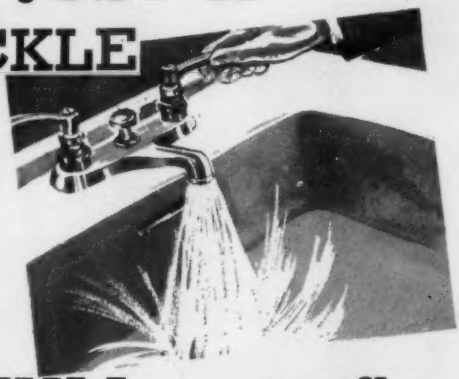
Automatic Controllers of the Phenol Content in Water. V. FAHNRICH. *Freiberger Forschungsh.* (Berlin), A170, 105 ('60). The advantages and disadvantages of com. installations are thoroughly discussed and a newly developed analyzer described.—*CA*

Treatment of Water With Chlorine Dioxide to Improve Taste. M. ENGER. *Gas- u. Wasserfach.* (Ger.), 101:340 ('60). At times the Rhine H_2O has a very disagreeable moldy-musty taste and odor. This can be reduced from a peak taste value of 40 or higher to 15–20 by treatment with ClO_2 at the rate of 0.6 mg/l. Addn. of 0.8 mg/l ClO_2 almost completely removes the musty taste, but replaces this with a taste of Cl or ClO_2. About 20% of the org. substance is broken down. Apparently ClO_2 reacts with the substances giving the moldy-musty taste to form labile compds.; with low ClO_2 dosages this taste reappears at some distance from the treatment plant. Under normal conditions the residual taste and odor are very slight, but with low levels of the Rhine River and very high contamination rates (as in 1959) the H_2O is unsatisfactory even after treatment.—*CA*

Treatment of Water by Storage, Coagulation, and Decantation. P. BLANCHARD. *Tech. Sci. Munic.*, 54:1:9; 54:2:51; 54:3:81; 54:4:129 ('59). This paper represents the French report on the Congres de Bruxelles (1958) of the International Association for Water Distribution. It is concerned with as complete as possible a description of the treatment of raw river water by storage, coagulation, and decantation without considering the related chemical processes. Terms are defined, techniques outlined in detail, formulas for the several processes are given, and a number of types of installations for each type of process are described and illustrated.—*PHEA*

Water Sterilization. J. VAN TILBURG. *J. Sci. Food & Agr.*, 10:240 ('59). A mixture of Cl_2 and O_2 or O_2-containing gas (air) is brought into contact at very high velocity with the water to be treated, the velocity being obtained by compression and subsequent expansion of the gas which is preferably introduced into the water at a no. of points to effect a stagewise purification. The purified water is substantially neutral, tasteless, odorless, and non-irrit nt. The reactions involved are similar to those in the "ISO" process, but the separation of the Cl_2 into its isotopes in that process is avoided.—*PHEA*

NOT JUST A TRICKLE



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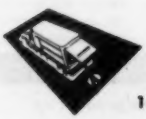

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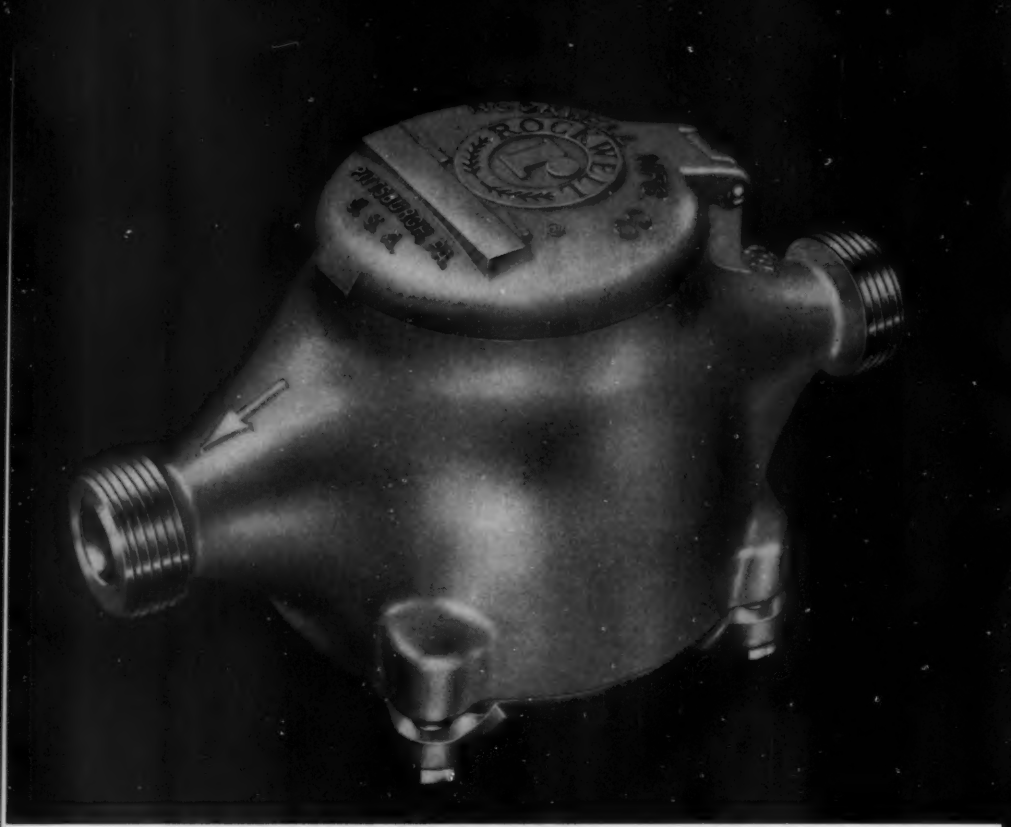

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The Rockwell Sealed Register "Magnetic" meter is *not* an adaption of any previous design.

Starting from scratch, Rockwell engineers could and did develop an all-new meter, one that did not compromise any desirable feature.

For instance, they materially *reduced* the number of working parts *instead of adding more.* They made this meter tamper-proof. Greater accuracy was engineered into the design.

From a maintenance standpoint, the Rockwell Sealed Register* meter is by far the *easiest* and *most economical to repair.*

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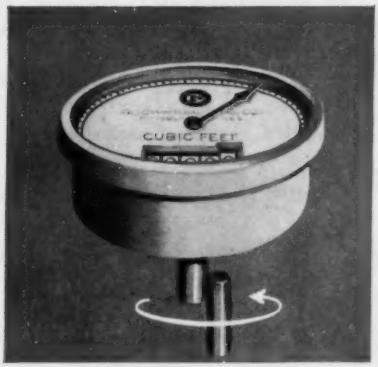
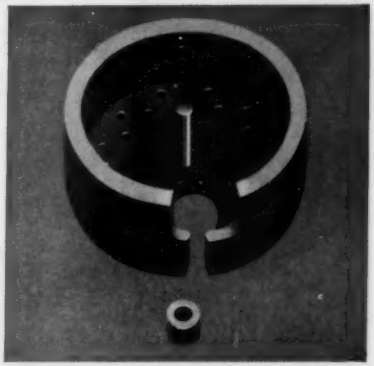


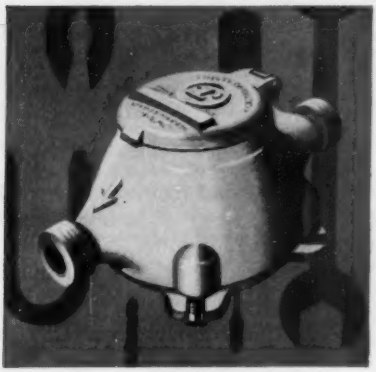
STRAIGHT LINE MAGNETIC DRIVE

A simple, powerful magnetic coupling transmits every motion of the measuring chamber directly to the sealed register in a vertical line. The permanent Alnico magnets are completely sealed. Their strength will not deteriorate with time.



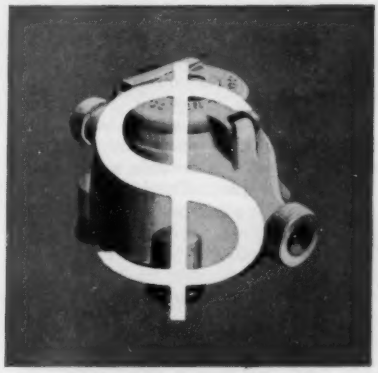
ONLY TWO REPAIR PARTS NEEDED

The piston and piston roller are the only parts operating in water. These two parts are all you need as compared to the large number required to repair other meters. Using only a wrench, anyone can replace these parts fast.



COMPLETELY TAMPER-PROOF

The sealed register is recessed into the main casing. Even if dismantled, the meter won't work without the register and the register won't turn without the meter. With this meter you'll stop tampering—stop losing important revenue.



COST NO MORE, EARN MORE, SAVE MORE

These better "magnetic" meters cost you no more to buy and cost you much less to maintain than other types of more complicated design. Since they have the fewest parts to wear they are easiest and most economical to repair.

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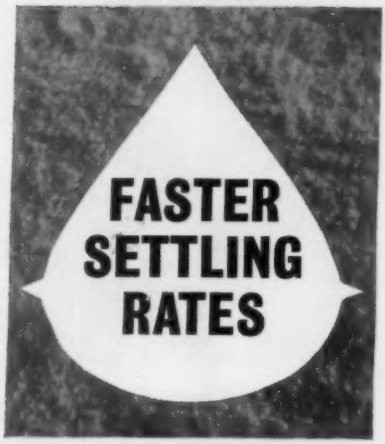

Not long ago, a water plant in the East began adding 1 ppm of a new coagulant aid called "Wisprofloc-20" to its settling tanks.

Today that plant is spending ⅓ less for coagulant dosage, getting more clarified water per day with retention time only half what it was before, and producing such high quality water that filter runs are longer.

Wisprofloc-20 is a non-toxic, U.S. Public Health Department approved, coagulant aid for potable water treatment. It is highly effective over a wide pH range, in all types of clarification systems.

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For details on Wisprofloc-20, or any specific problem you may have on water treatment chemicals, write: Ionac Chemical Company, Dept. JA-91, Birmingham, N.J. (In Canada, contact Pfaudler Permutit Canada Ltd., Toronto.)

IONAC CHEMICAL COMPANY
DIVISION OF PFAUDLER PERMUTIT INC.

(Continued from page 54 P&R)

year of a Division of Material Sciences, to promote knowledge of the fundamental nature of materials.

As for AWWA, there are those who are looking forward to its becoming the American Water and Wastes Association, but we, of course, cherish the day when it will admit to being the American Water Words Association.

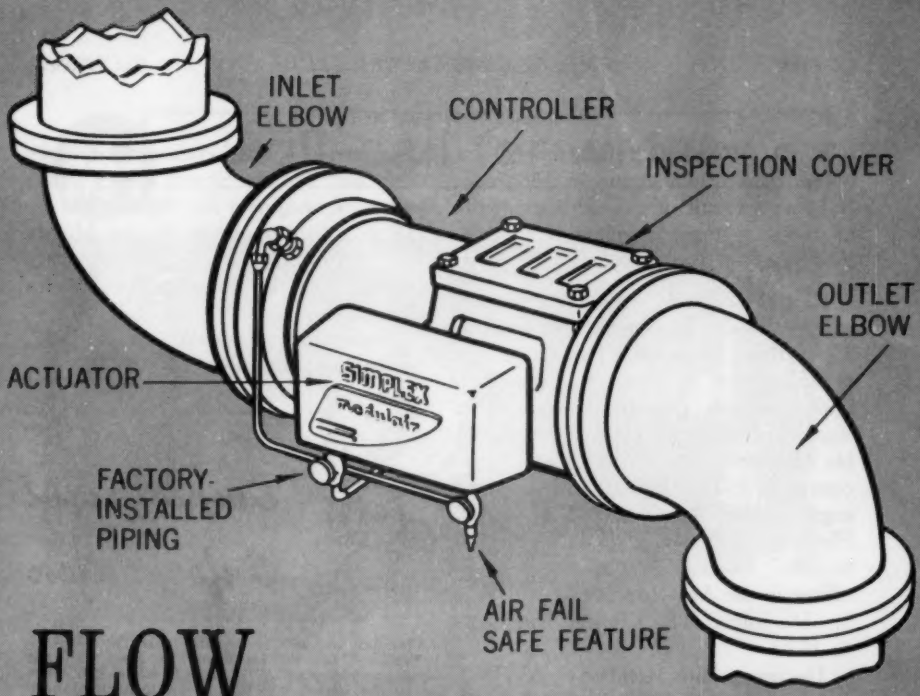
Clinton L. Bogert has retired from the firm of Clinton Bogert Engineers, New York City, but will continue to serve as a consultant to the firm.

'Why not adopt an elephant?' was the pitch of a full-page ad in the Nairobi, Kenya, *Daily Nation* last July, as the drought there reached mammoth proportions. Actually adoption, on the basis suggested by the Kenya National Parks, did not involve domiciliary care, but only the provision of adequate water supply, at a cost of slightly more than $5 per year per adult, and half that much per baby, elephant. All of which should go to show that the price of water per capita or per pachyderm is ridiculously low.

C. C. Randall has retired from his position of water superintendent for the town of Lincolnton, N.C., after 25 years of service with the community.

The Office of Resource Development (Environmental Health) within the Bureau of State Services was established recently, as a step in the reorganization of USPHS to provide a more coordinated, integrated, and intensive focus upon the public health problems created by environmental hazards. The new office is headed by Frank A. Butrico.

(Continued on page 82 P&R)



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How to control it economically with this simple, modern "box on a pipe."

This is the Modulair Type "P" rate-of-flow controller, for your filter effluent piping.

You install it almost as easily as a piece of pipe, and its design is so utterly simple that you have almost no maintenance cost.

In fact, the minute you put this venturi-actuated, fully pneumatic controller to work, you get these new savings:

1. No valve operator
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3. No hydraulic valves
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5. No "spaghetti" of complicated piping
6. No pilot valve or valve shaft
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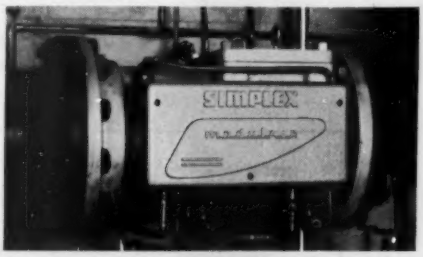
8. No floor drain
9. Almost no maintenance

You save space, too, because the "P" controller has the shortest laying length of any, in addition to being entirely preassembled, with all working parts enclosed.

Send for our Bulletin 951, for details on space and cost savings of the "P" controller. Compare them with your present method of flow control. No obligation.



Note how Modulair "P" flow controller requires very little space in filter effluent line.

SIMPLEX
VALVE AND METER COMPANY
a division of PFAUDLER PERMUTIT INC.
Lancaster, Pennsylvania

(Continued from page 80 P&R)

R. D. Wood Co. has moved its offices from Philadelphia to Florence, N.J., as a result of consolidation with its former manufacturing company, Florence Pipe Foundry & Machine Co.

Daniel E. Davis, formerly a partner of The Chester Engineers, died on Jun. 25, 1961, at Sewickley, Pa., at the age of 75. Born in 1886, at Columbus, Ohio, he was graduated from Ohio State University in 1908 and received his M.S. from the University of Wisconsin in 1913. He was an assistant engineer for the firm of Chester & Fleming, of Pittsburgh, Pa., from 1913 to 1917, when he left to serve as an officer in the Army during World War I. He joined The Chester Engineers in 1919.

He was a Life Member of AWWA, having joined in 1930. In 1947 he received the Fuller Award. Other professional affiliations included ASCE (Life Member) and WPCF.

Carl F. Mau, former vice-president, California Water Service Co., died Jul. 13, 1961, in San Jose, Calif., at the age of 65. After attending the University of California in Berkeley, he served in the Army Air Force during World War I, following which he began his engineering career in Northern California. Before joining the California Water Service Co., he held assignments as city engineer for Redding and Mount Shasta City, Calif., and county engineer for Shasta County. He was also employed by the Metals Exploration Co., Pacific Gas & Electric Co., and the State Public Utilities Commission.

A member of AWWA since 1937, he was also a member of ASCE.

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Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

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U.S. Department of Commerce lists 85 midwest cities today as having adequate and efficient water works, with an overload capacity 20% in excess of maximum-day load. But the Department also lists 16 midwest water works as inadequate and 18 additional water systems as definitely deficient! Here lives some 15 million Americans – But over 3 million of them have inadequate water supply facilities!

Annual property loss from fire in the U.S. in 1959 was in excess of 1 billion dollars. At the same time, approximately half of the water works facilities of the U.S. are inadequate or deficient in capacity. Considering present water distribution deficiencies and increasing demand due to population growth, it is estimated that water supply facilities will need to be doubled within the next 20 years.

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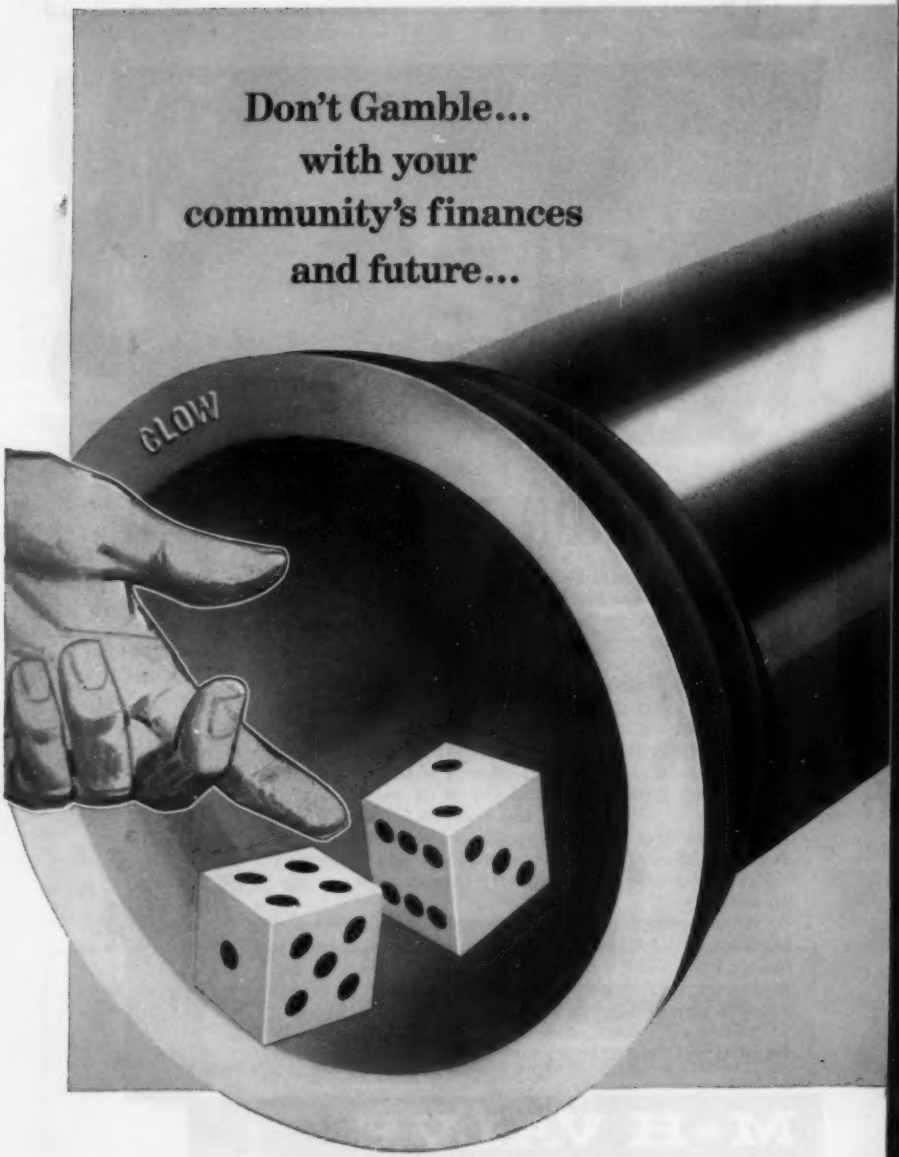
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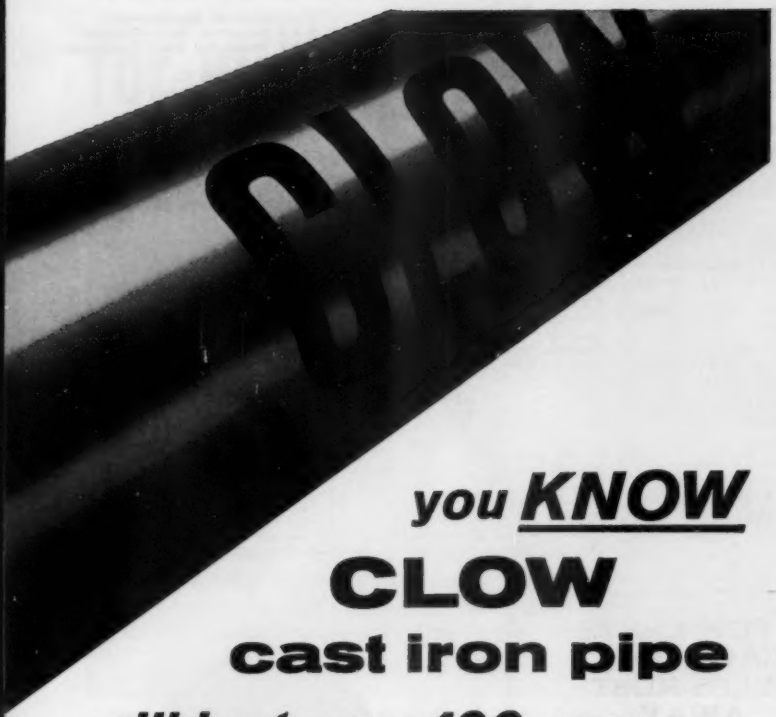

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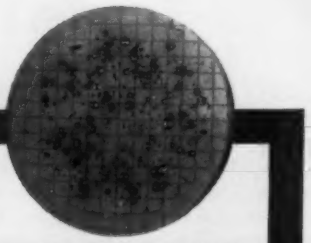

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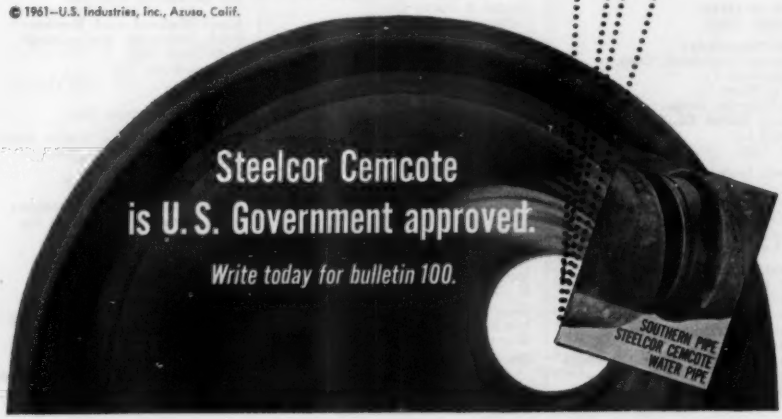

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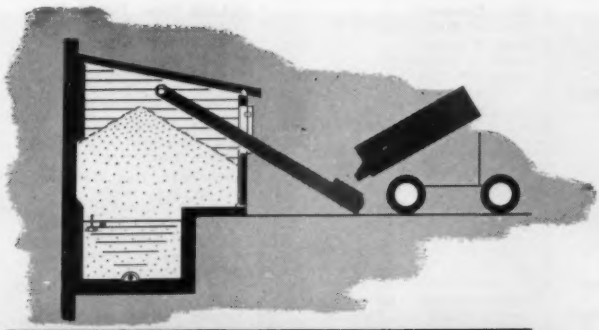
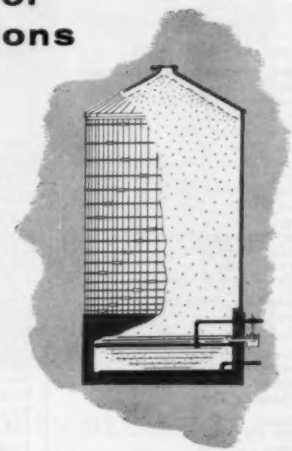


BRINE LEVEL

How it can affect design of water softening installations

What's the best brine level for a 500-gallon-per-hour salt dissolver? Your answer is bound to influence the type of dissolver construction needed, as well as the cost of operating the equipment. The lower the level, the less expense there will be in waterproofing the bottom portion of the dissolver. But too low a level can seriously reduce brine-making efficiency, and thus boost brine-making costs.



It is essential, therefore, to reach the best compromise between original construction cost and subsequent operating expense by specifying the correct brine level. Here's where International Salt Company is ready to help. 50 years of experience and continuing research in all phases of salt handling and brine production make International the leading authority on matters concerning salt purchase, storage and dissolving for regenerating ion exchangers. This knowledge is especially valuable in view of the ever-growing amounts of brine being used today.

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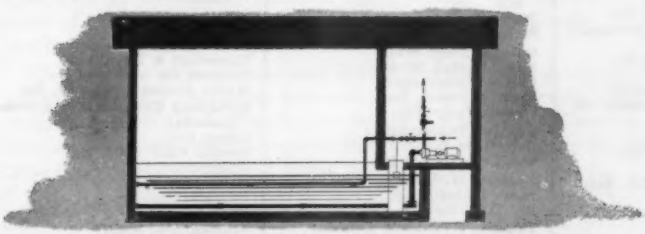

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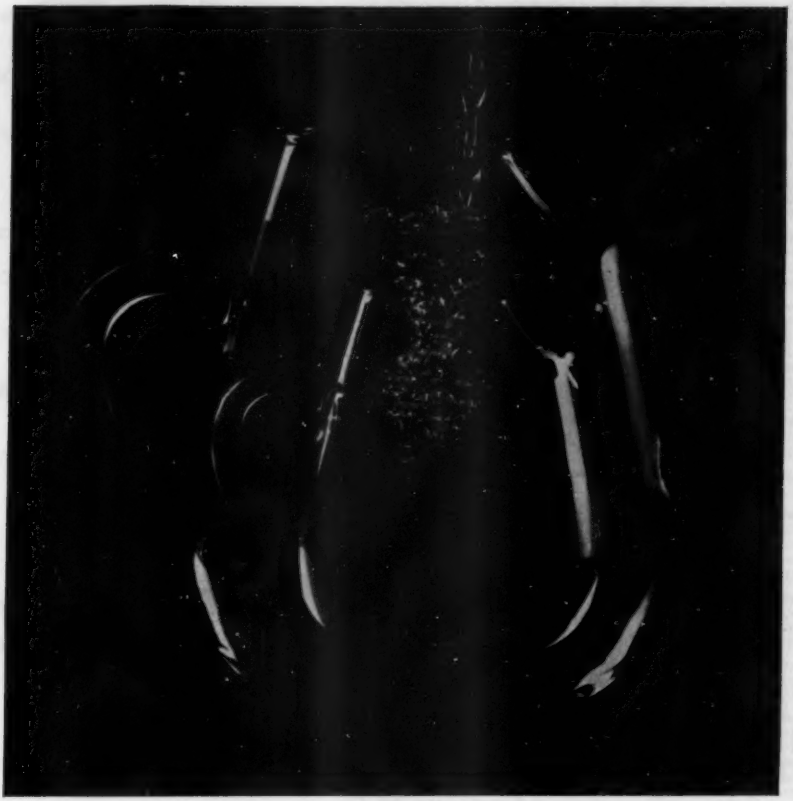

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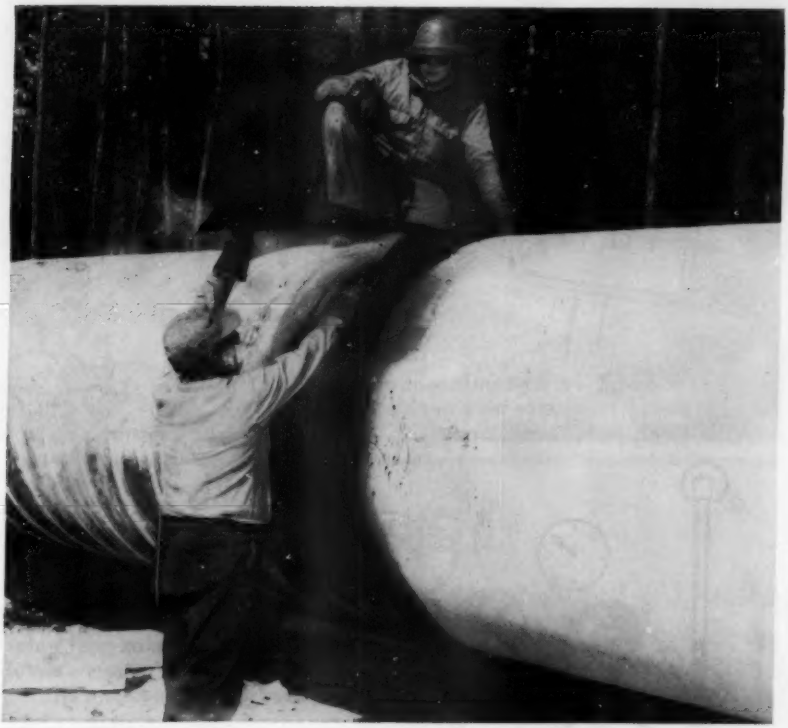
Zeolite: see Ion Exchange Materials

A complete Buyers' Guide to all water works products and services offered by AWWA Associate Members appears in the 1959 AWWA Directory.



Bitumastic No. 70-B Enamel Chosen Again After 23-Year Perfect Service Record

Over 23 years ago, the City of Birmingham, Alabama chose steel pipe lined and coated with Bitumastic® No. 70-B AWWA Enamel for use in unusually difficult service conditions: the coated pipe had to withstand severe soil subsidence and a high degree of soil acidity. After 23 years of service on this earlier pipeline, Birmingham's Industrial Water Board specified this Koppers coal-tar coating once more for protection of its newest water service installation—a 60-inch steel line that will supply the city with an additional 75 million gallons of water per day.

Bitumastic Jet Set, the Koppers fast-drying primer, was applied to the 40-foot steel pipe lengths, and each section was then given a shop coating of Bitumastic No. 70-B Enamel on the interior and exterior walls. Pacific Pipeline Construction Company, of Montebello, California, subcontractors to Morrison-Knudsen Co., prime contractors, performed this coating operation. Koppers Contract Department completed the joint coating work in the field.

The family of Bitumastic coatings has built many performance records of this type in unusually difficult service conditions. For further information, write: Koppers Company, Inc., Tar Products Division, Pittsburgh 19, Pa.

KOPPERS

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BITUMASTIC
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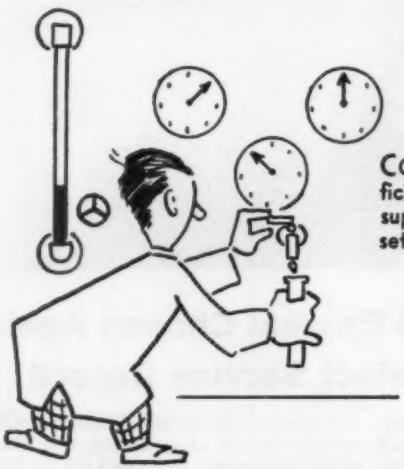
another fine product of COAL TAR

TO HELP CONSERVE YOUR WATER SUPPLY

WATER is becoming more scarce, more expensive to obtain, treat, pump and deliver.



CONSERVATION starts with the efficient handling and delivery of water supplies — including meters, meter setting and testing equipment.

THE new Ford Catalog No. 56 is a water man's "bible". It not only pictures and lists the latest in meter servicing equipment, but it contains diagrams and much helpful data for the express purpose of conserving water through more efficient use of meters. It is available on request. Send for your copy today.

FORD

FOR BETTER WATER SERVICES

THE FORD METER BOX COMPANY, INC. Wabash, Indiana

La Mariposa Water Treatment Plant: Dorrco Monorakes in rear basins; Flocculators in foreground.

CARACAS, VENEZUELA

Dorr Monorakes, Flocculators Boost Capacity

Caracas, with a population over one million and rated one of the world's fastest growing cities, recently completed a second addition to its La Mariposa Water Treatment Plant to increase capacity from 16 to 80 MGD.

The original plant was equipped with two Dorrco Squarex Clarifiers, 115′ square by 14′ s.w.d., and two Type "T" Flocculator units for basins 115′ long by 40′ wide by 11′ s.w.d.

To achieve the five-fold boost in capacity, Dorr-Oliver equipment was again chosen. The recent additions comprise three Type "A" Dorrco Monorakes for basins 202′ long by 65′ wide by 14′ deep, three Type "T" Dorrco Flocculators 50′ long by 65′ wide by 11′ deep, and twelve new Filters.

DESIGN ENGINEERS: Instituto Nacional de Obras Sanitarias.

Every day over 8½ billion gallons of water are treated by Dorr-Oliver equipment.

Squarex, Dorrco—T.M. Reg. U.S. Pat. Off.

DORR-OLIVER

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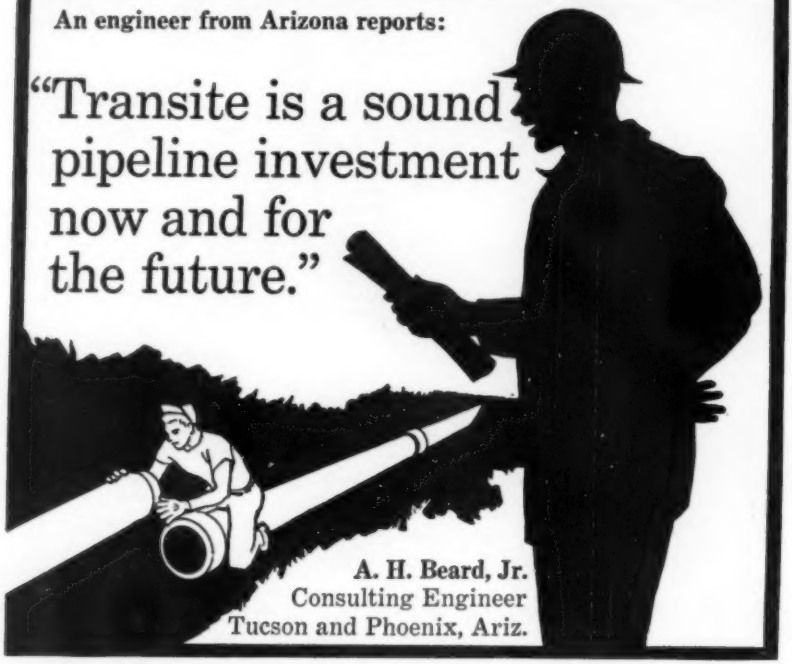
An engineer from Arizona reports:

"Transite is a sound pipeline investment now and for the future."



A. H. Beard, Jr.
Consulting Engineer
Tucson and Phoenix, Ariz.

"When considering a pipe material for water and sewage projects, 'value' analysis plays an important part in our choice. One of the main questions is whether the pipe will perform reliably now *and* in the future with cost advantages to the client.

"Experience has shown that Johns-Manville Transite® Pipe offers the value we seek. It has proved reliable and at very favorable costs. In addition to savings in handling and installing, Transite's unique Ring-Tite® joints assure that leakage tests will not upset job costs. In numerous tests, Transite lines have regularly been under the 'allowable' specification.

"Installations as old as Transite itself show this pipe outstanding under flexure, crush and hydrostatic conditions. Lengths of Transite excavated here in Arizona for tests showed no signs of internal corrosion after 20 years of dependable service."

For full details, write to Johns-Manville, Box 362, JA-9, N. Y. 16, N. Y. In Canada: Port Credit, Ontario. Cable: Johnmanvil.

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